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Ultrathin Portland Cement Concrete Overlay Extended Evaluation

Interim Report
July 2002

Sponsored by the
Iowa Department of Transportation
Project Development Division and
the Iowa Highway Research Board

Iowa DOT Project TR-432

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Department of Civil and Construction Engineering

Disclaimer

“The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Iowa Department of Transportation nor the United States Department of Transportation, Federal Highway Administration.”

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Acknowledgements

This report would not have been possible without the assistance of the Iowa DOT Cedar Rapids Construction Residency Staff, Hawkeye Paving, Iowa DOT Central Office of Maintenance and District 6 Maintenance Staff, and Robert Given of the Iowa Concrete Paving Association. The professionalism and cooperation of all involved in this project are appreciated.

Abstract

The Iowa Department of Transportation (Iowa DOT) UTW Project (HR-559) initiated Ultra-Thin Whitetopping in Iowa. The project is located on Iowa Highway 21 between Iowa Highway 212 and U.S. Highway 6 in Iowa County, near Belle Plaine, Iowa.

The above listed research project lasted for five years, and then was extended for another five year period. The new phase of the project (TR 432) was initiated by removing cracked panels existing in the 2-inch thick PCC sections and replacing them with three inches of PCC. The project extension provides an increased understanding of slab bonding conditions over a longer period, as well as knowledge regarding the behavior of the newly rehabilitated areas.

This report documents the rehabilitation of the PCC patching of all fractured panels and several cracked panels, taking place in September of 2001.

INTRODUCTION

The Engineering Research Institute of Iowa State University, along with the Iowa Department of Transportation and the Federal Highway Administration, is conducting ongoing research of the performance of thin concrete overlays on highway pavements.

The project being researched is a 7.2-mile section of Iowa Highway 21, south of Belle Plaine, Iowa. The original project began in July 1994 and ended on July 1, 1999. The current phase of this research project began on August 3, 1999 and will continue until August 2004. This phase of the project will provide an opportunity for the Iowa Department of Transportation and Iowa State University to increase their knowledge of potential rehabilitation methods and other alternatives involving PCC thickness and transverse joint spacing.

This report contains information on, research objectives, pertinent construction history, data collection methods, and data analysis techniques in this study. Appendices in this report include visual distress data, deflection load transfer and backcalculated modulus values, all in the form of graphs.

RESEARCH OBJECTIVES

The goal of this project is to evaluate the degree of interface bonding between PCC and ACC layers over time. In conducting the research, joint spacing, PCC thickness, use of concrete fibers, surface preparation, and joint sealing are under consideration. The objective of this research will be accomplished by conducting laboratory and field tests, collecting data, and analyzing the data appropriately. Following these steps, a report containing information regarding the various research components will be produced. The report will document practices and results, as well as information concerning the achievements of the research.

The extension of the Iowa Highway 21 (TR-432) research project should result in increased knowledge concerning acceptable construction practices and highway performance. The specific objectives for the extension project are:

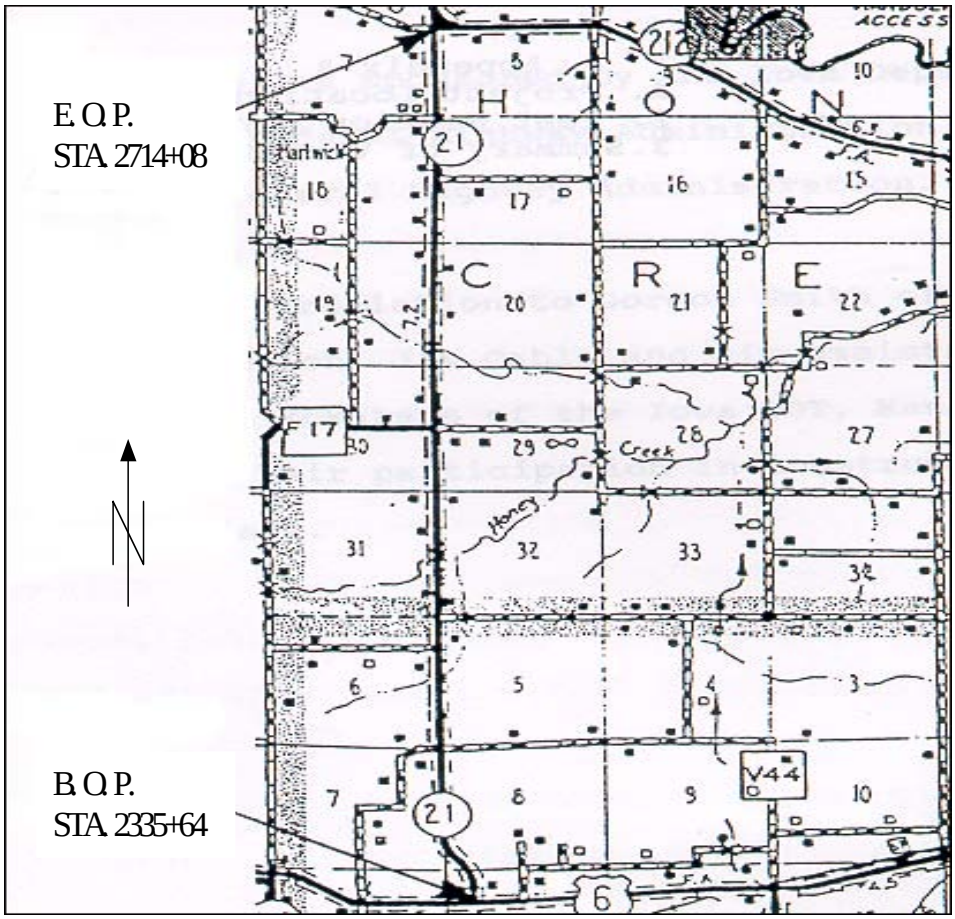
- The condition of the underlying ACC is to be evaluated at specified rehabilitation areas.
- Various slab removal methods are to be evaluated in order to determine removal techniques that will not damage the surrounding pavement.
- ACC base preparation is also to be evaluated. This will involve the observation of the level of effort that was required to prepare the ACC base on which the new PCC was placed, as well as the condition of the base prior to that placement of PCC.
- An evaluation of the possible methods of joint formation is an objective of this project.

- Due to the absence of three-inch thick PCC test sections during the first five years of the research project, it is now desired to analyze the benefits of fiber addition in such sections.
- The general performance of all rehabilitated pavement areas will be evaluated.
- The extended performance of non-rehabilitated pavement areas will be evaluated.
- It is to be determined whether UTW design procedures are compatible with the standards set by the Portland Concrete Association (PCA) and the American Concrete Paving Association (ACPA).

TEST SITE DESCRIPTION

The Iowa Highway 21 project is a 7.2 mile long stretch of roadway that extends from U.S. 6 to Iowa 212 in Iowa County. Figure 1 illustrates the project location.

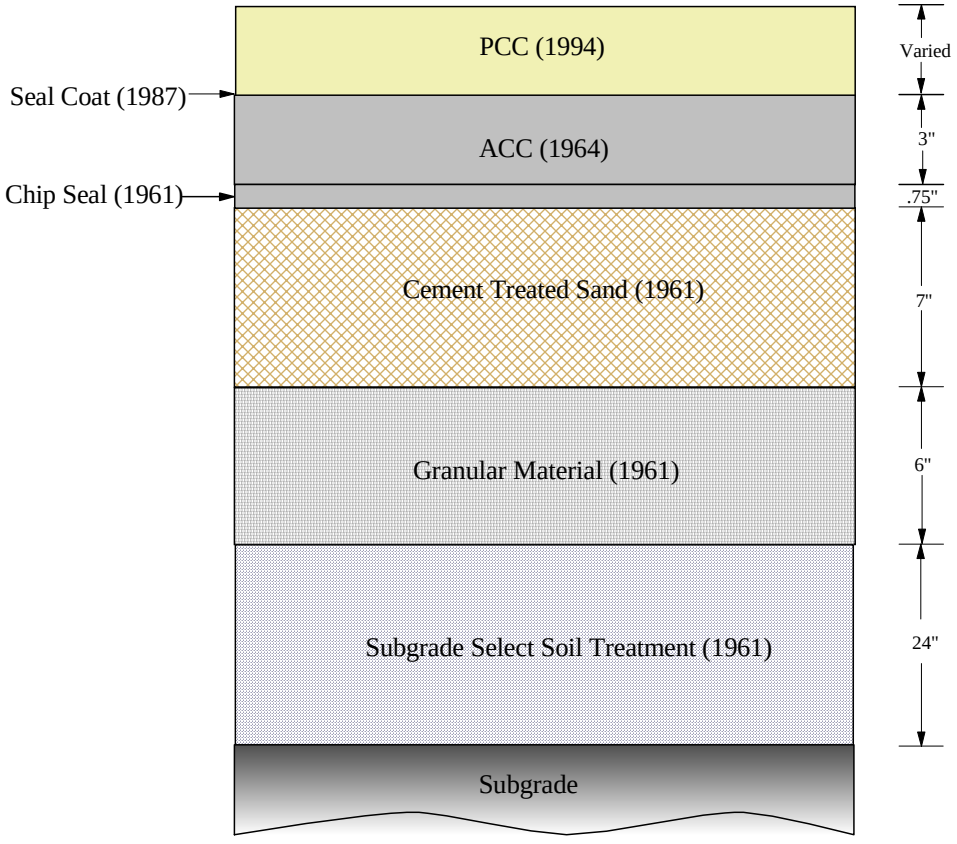
Figure 1: Project Location



This portion of Iowa 21 is a two-lane roadway, 24 feet in width, with 9-foot wide granular shoulders and open ditch drainage. The existing alignment was graded in 1958. A granular driving surface was used until 1961, at which time improvements were made. The improvements included replacing the original sub-grade with select material 2 feet in thickness and 24 feet wide, centered on the roadbed. The select material was overlaid

with six inches of granular material, seven inches of cement treated sand (CTS), and 0.75 inches of chip seal. The 9-foot granular shoulders were also constructed at this time. The chip seal was used as the driving surface until 1964, when three inches of type B asphalt cement concrete (ACC) were placed over it. In 1987, a seal coat of negligible thickness was applied to the ACC surface. Ultra-thin whitetopping was placed on the ACC in 1994. All pavement layers were designed and placed according to effective Iowa State Highway Commission (ISHC) or Iowa DOT specifications at the time of contract letting. Figure 2 shows the pavement layers and the dates of their construction.

Figure 2: Pavement layers and the dates of their construction



In June and July of 1994, a thin portland cement concrete overlay was placed over top the Seal Coat. PCC thicknesses ranged from 2 in to 8 in. Different joint spacings were used in the PCC, ranging from 2 ft squares to 15 ft by 12 ft panels. Also, fiber reinforcement was used from stations 2342+00 to 2415+00 and 2540+00 to 2631+00.

On August 2 1999, areas of PCC were selected for rehabilitation. Panels selected were observed to have longitudinal cracks or corner cracks. Also, fractured panels (panels broken into 4 or more pieces) and areas of potential de-bonding were chosen for replacement. In addition to individual panel rehabilitation, an 804-foot section in the southbound lane was selected for lane replacement. This area is a CIPR surface preparation, which had exhibited characteristics of weak ACC base material. Table 1 shows information regarding size and panel location of the rehabilitated areas.

Patch Number	Station	Panel Location*	Lane	Size (ft)	Quantity	Area (ft^2)
1	2369+37	R 5, 6	NBL	2 x 2	4	16
2	2380+32	R 5	NBL	2 x 2	7	28
3	2383+06	L 4	SBL	2 x 2	3	92
4	2383+46	R 2	NBL	2 x 2	2	8
5	2385+46	R 2	SBL	2 x 2	2	8
6	2384+17	R 5, 6	NBL	2 x 2	25	100
7	2384+60	R 5	NBL	2 x 2	9	36
8	2384+91	R 5	NBL	2 x 2	2	8
9	2385+13	L 4	SBL	2 x 2	24	96
10	2385+52	R 5, 6	NBL	2 x 2	29	116
11	2386+37	L 1	SBL	2 x 2	3	12
12	2386+43	L 4	SBL	2 x 2	2	8
13	2386+59	L 4	SBL	2 x 2	8	32
14	2386+75	L 5	NBL	2 x 2	2	8
15	2389+11	R 3	NBL	4 x 4	7	112
16	2389+83	R 3	SBL	2 x 2	19	304
17	2391+20	L 2	NBL	2 x 2	5	80
18	2392+18	R 3	SBL	2 x 2	40	640
19	2392+50	L 3	SBL	2 x 2	21	336
20	2448+14	L 2 – 6	SBL	2 x 2	65	260
21	2454+48	R 1 – 6	NBL	2 x 2	390	1560
(end of pave)	2455+78					
22	2454+48	L 1 – 6	SBL	2 x 2	390	1560
(end of pave)	2455+78					
23	2550+67	L 3	SBL	2 x 2	8	128
24	2552+16	L 3	SBL	2 x 2	3	48
25	2552+83	L 3	SBL	2 x 2	12	192
26	2553+60	R 3	NBL	2 x 2	1	16
27	2622+00	L 3 – 5	SBL	2 x 2	17	68
28	2623+00	L 5, 6	SBL	2 x 2	16	64

Table 1

NBL = North Bound Lane
SBL = South Bound Lane
* For example, “R 3” indicates that a removal area is located three panels to the right of the center line when oriented from South to North

In August of 2001, more areas were selected for rehabilitation. In several sections, PCC patching of all cracked or fractured panels was accomplished. In several other sections, PCC fractured panels were replaced and a 3 inch ACC overlay was placed over the sections. Minimal patch depth was 4 inches and the new panels were cut to the same size as the old panels in these areas. Table 2 identifies the stations where patching occurred.

Station	Lane	Dimension (ft)	Existing Depth (in)	Panel Size (ft)
2364+00	R	44 x 6	4	4 x 4
2364+00	L	6 x 6	4	4 x 4
2368+00	R	6 x 4	4	2 x 2
2369+26	R	2 x 2	4	2 x 2
2369+30	R	2 x 4	4	2 x 2
2369+36	R	2 x 4	4	2 x 2
2369+44	R	2 x 2	4	2 x 2
2369+64	R	2 x 4	4	2 x 2
2383+72	L	6 x 4	2	2 x 2
2384+20	R	34 x 2	2	2 x 2
2384+46	R	8 x 4	2	2 x 2
2385+86	R	34 x 4	2	2 x 2
2389+40	R	28 x 4	2	4 x 4
2389+92	L	12 x 12	2	4 x 4
2390+36	R	12 x 4	2	4 x 4
2391+72	R	52 x 4	2	4 x 4
2391+72	L	12 x 4	2	4 x 4
2391+96	L	16 x 4	2	4 x 4
2393+28	L	32 x 4	2	4 x 4
2393+72	R	28 x 4	2	4 x 4
2447+68	L	4 x 2	4	2 x 2
2448+16	L	14 x 6	4	2 x 2
2456+00	R	6 x 12	2	6 x 6
2538+36	R	24 x 6	6	6 x 6
2541+20	L	4 x 4	2	2 x 2
2541+20	L	6 x 2	2	2 x 2
2541+20	R	2 x 2	2	2 x 2
2546+68	L	2 x 4	2	2 x 2
2547+00	R	12 x 4	2	4 x 4
2547+60	L	8 x 4	2	4 x 4
2547+84	L	4 x 4	2	4 x 4
2548+36	R	4 x 12	2	4 x 4
2549+00	L	16 x 4	2	4 x 4
2549+04	R	8 x 4	2	4 x 4
2550+36	L	4 x 4	2	4 x 4
2551+00	L	44 x 8	2	4 x 4
2551+36	L	12 x 4	2	4 x 4
2553+44	L	4 x 4	2	4 x 4
2623+84	L	60 x 6	2	2 x 2
2623+84	R	6 x 8	2	2 x 2
2623+50	L	32 x 2	2	2 x 2
2625+50	L	8 x 12	2	4 x 4
2625+60	R	8 x 12	2	4 x 4
2689+20	L	48 x 6	6	12 x 12
2692+16	L	20 x 8	2	4 x 4
2692+32	R	16 x 4	2	4 x 4

Table 2

DATA COLLECTION

A visual distress test is performed twice a year by the main author and his research assistants. The tests were performed to identify the impact of the freeze and thaw cycles in the spring and again in the fall to identify the impact of heavy loads on pavement performance. These surveys were conducted in April or May and also in September or October of each year. Graphs illustrating the results of the visual distress testing over time can be found in Appendix A.

Non-destructive deflection testing is performed annually by ERES Consultants, using a falling weight deflectometer (FWD). The FWD has seven deflection sensors spaced at 0, 12, 24, 36, 48, 60, and 72 inches from the center of the load plate. At each of the total 39 test slabs, drops were made at target loads of 9000, 12,000, and 16,000 lbf. Deflection testing is performed in the northbound lane between stations 2346+00 and 2694+50 and in the southbound lane between stations 2455+00 and 2697+25. A drop sequence was performed at each test slab at the approach side of the transverse joint and at the slab center along the outer wheel path.

Data is being collected on this project in order to evaluate numerous variables used in ultra-thin whitetopping. Some of the variables to be discussed include:

- ACC base preparation involving the condition of the ACC base prior to PCC placement and the different methods of base preparation.
- The use of fiber reinforcement throughout the length of the project.
- Evaluation of the different joint spacings corresponding with thickness of pavement.

- Comparison of the concrete sections to the asphalt sections at the end of the ten years.

The final analysis of the collected data will appear in a report in July of 2004.

DATA ANALYSIS

Visual Surveys

Visual Distress Data was analyzed using graphs to depict type of cracks, extent, and test section location. These graphs help to illustrate what type of ACC base preparation is the most effective, what thickness works best to survive Iowa freeze and thaw cycles and vehicle loadings, and also what joint spacing perfoms best for different thicknesses. The visual distress data also is used to determine the impact of fibers in ultra-thin concrete layers. The graphs depicting this data can be found in Appendix A.

Deflections

In order for jointed concrete pavements and jointed concrete overlays to perform well, the concrete must have the ability to distribute loads and stresses from one slab to another. This is measured with the FWD and is referred to as *joint load transfer efficiency*. In order to measure deflection load transfer efficiency, a load plate is placed exactly at the edge of a pavement joint such that only one of the slabs adjacent to the joint is loaded. Two deflection sensors are then placed equidistant from the joint, with one on each side of the joint. The ratio of the deflections of the unloaded side to the loaded side of the joint is known as *deflection load transfer efficiency*.

The deflection data can also be used to backcalculate the pavement layer modulus. Pavement models have been developed which calculate the deflection of pavements, provided the inputs of layer types and thicknesses, bonding conditions between pavement layers, radius of applied load, and magnitude of applied load. To find the modulus, collected deflection data is used to work backwards through the pavement

models. The values input for the backcalculation can be found in Table 3. Elastic properties of each pavement layer, including Poisson's ratio, seed modulus, and modulus boundaries and assumed based on layer types and engineering judgement. The degree of bonding between layers was assumed to be full bonding for all layers, except for the PCC/AC interface, which was analyzed for both bonded and unbonded conditions. The actual bonding conditions in the field for all layers are unknown.

Pavement Layer Type	Thickness, in	Poisson's Ratio	Modulus seed values and boundaries, psi			Bonding Conditions
			Minimum	Seed	Maximum	
PCC	2.75 to 9.80	0.15	3,000,000	3,500,000	10,000,000	Bonded and Unbonded
Combined AC and CTB	10.75	0.40	40,000	50,000	2,500,000	Bonded
Combined subbase and subgrade	240	0.45	5,000	6,000	30,000	___

Table 3. Summary of Backcalculation input values

The results of load transfer and backcalculation can be found in Appendices B & C.

SUMMARY

The 2001 rehabilitation of Iowa Highway 21 was in accordance with specified construction procedures and progressed with no major setbacks or concerns. Proper construction of the project shall provide a good basis for data collection and analysis for the remainder of the five years. The desired outcome is to continue to learn more about the bonding characteristics associated with a PCC/ACC in terms of joint spacing, PCC thickness, use of fibers, surface preparation and the sealing of joints.

Sections showing transverse cracking include Section 39, a 2 in. depth, 4 ft. square section, with more than 3% of slabs cracked; Section 43, a 4 in. depth, 6 ft. square section, with more than 2% of slabs cracked; Section 45, a 6 in. depth, 12 ft. square section, with less than 4% of slabs cracked; and Section 1, a 8 in. depth, 12 ft. by 20 ft. section, with more than 2% of slabs cracked. The rest of the sections exhibit less than 1% of transversely cracked slabs.

Longitudinal cracking is occurring in some sections, including Section 10, a 2 in. depth, 2 ft. square section with less than 4%; Section 11, a 2 in. depth, 4 ft. square section, with more than 11%; Section 4, a 6 in. depth, 6 ft. square section, with more than 2%; Sections 3, 18, and 45, all 6 in. depth, 12 ft. square sections, with more than 2%; Section 1, a 8 in. depth, 12 ft. by 20 ft. section, with more than 12%; Section 31, a 8 in. depth, 12 ft. by 15 ft. section, with more than 3%; and Section 32, also an 8 in. depth, 12 ft. by 15 ft. section, with more than 12%. All other sections exhibit less than 2% longitudinally cracked slabs.

Section 39, a 2 in. depth, 4 ft. square section has more than 2% slabs exhibiting corner cracking. Section 62, identical to section 39, has more than 5% corner cracking.

Section 1, an 8 in. depth, 12 ft. by 20 ft. section is showing more than 9% of slabs with corner cracks. Section 32, an 8 in. depth, 12 ft. by 15 ft. section has more than 3 % of corner cracked slabs. Sections 10, 23, 52, 11, 53, 7, 29, 50, 1, 33, 45, and 60 exhibit less than 2% of slabs with corner cracks.

Joint spalls can be found in Sections 29, 43, 19, 25, 27, and 31, with less than 1% of joints spalled in each respective section. The rest of the sections not mentioned above have very minimal spalling.

Section 32, an 8 in. depth, 12 ft. by 20ft. slab, has more than 2% of its slabs exhibiting popouts. Sections 62, 29, 41, 19, 25, 36, 46, 3, 14, and 60 have less than 1% exhibiting popouts, respectively.

Fractured slabs can be found in a few sections, including Section 62, a 2 in. depth, 4 ft. square section, with more than 5% of slabs fractured. Section 11, falling into the same catergory as Section 62, exhibits less than 1% of slabs fractured. Sections 10, 23 and 52, which are 2 in. depth, 2 ft. square sections are showing less than 1% of slab fractured. The remaining sections have minimal slab fracturing. Recall many of the previously fractured sections have been rehabilitated.

Sections 29, 52, 53 and 62 are showing minimal (less than 1%) signs of diagonal cracking. Section 52 is a 2 in. depth, 2 ft. square section; Sections 53 and 62 are 2 inches in depth also, and are cut into 4 ft. squares; while Section 29 is a 4 in depth, cut into 4 ft. squares. All other sections exhibit very minimal diagonal cracking.

The load transfer graphs, in general, do not show much variation between years. The load transfer value does not typically get smaller from year to year, but slightly increases and decreases in each respective year.

The modulus value graphs do not show a pattern at this time.

REFERENCES

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3. ERES Consultants. "Thin-Bonded Overlay Evaluation Project for Iowa Highway 21." Engineering Research Institute, Iowa State University, September 1996.

4. ERES Consultants. "Thin-Bonded Overlay Evaluation Project for Iowa Highway 21." Engineering Research Institute, Iowa State University, November 1997.

5. ERES Consultants. "Thin-Bonded Overlay Evaluation Project for Iowa Highway 21." Engineering Research Institute, Iowa State University, September 1998.

6. ERES Consultants. "Thin-Bonded Overlay Evaluation Project for Iowa Highway 21." Engineering Research Institute, Iowa State University, November 1999.

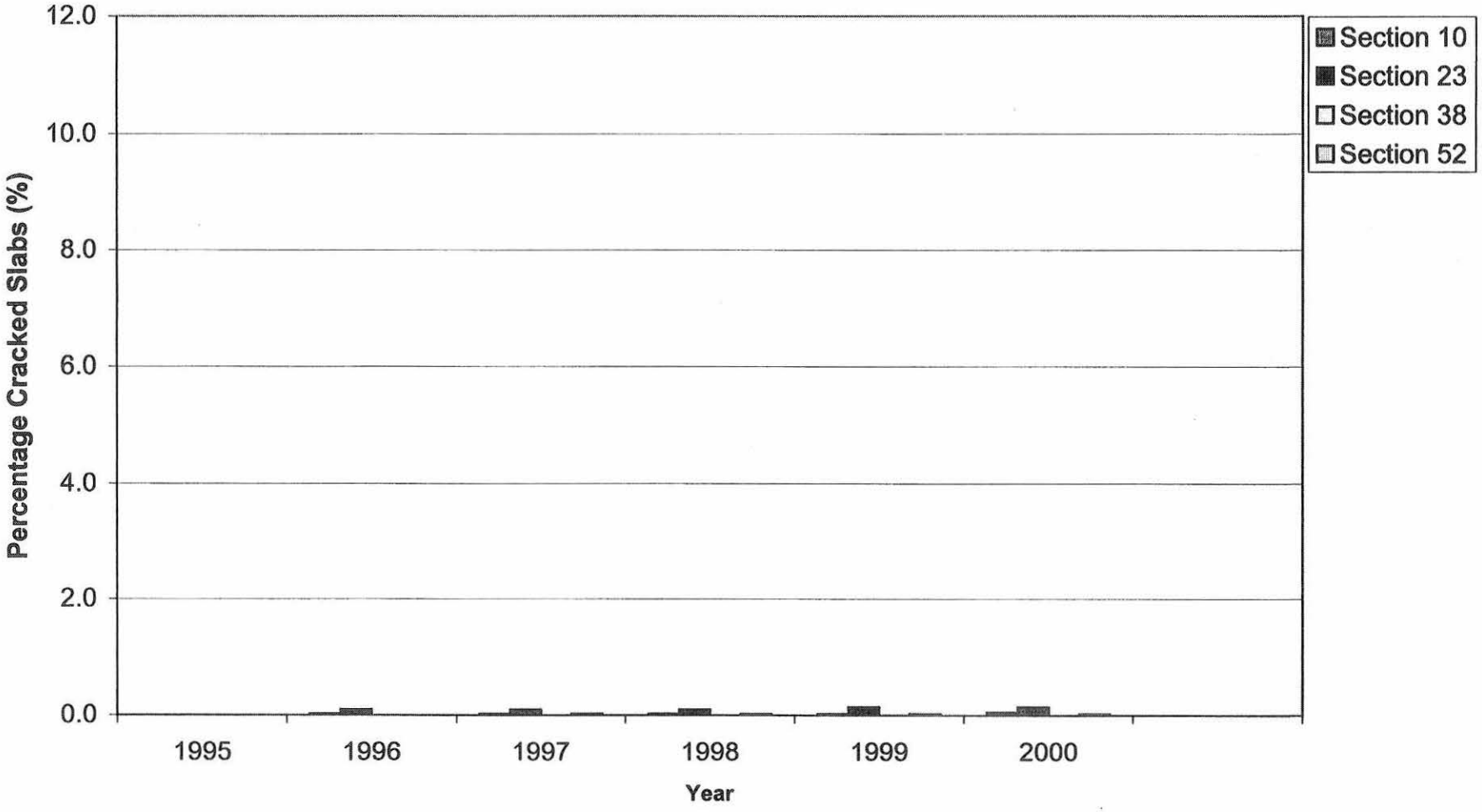
7. ERES Consultants. "Thin PCC Overlay Extended Evaluation." Engineering Research Institute, Iowa State University, October 2000.

8. ERES Consultants. "Thin PCC Overlay Extended Evaluation." Engineering Research Institute, Iowa State University, November 2001.

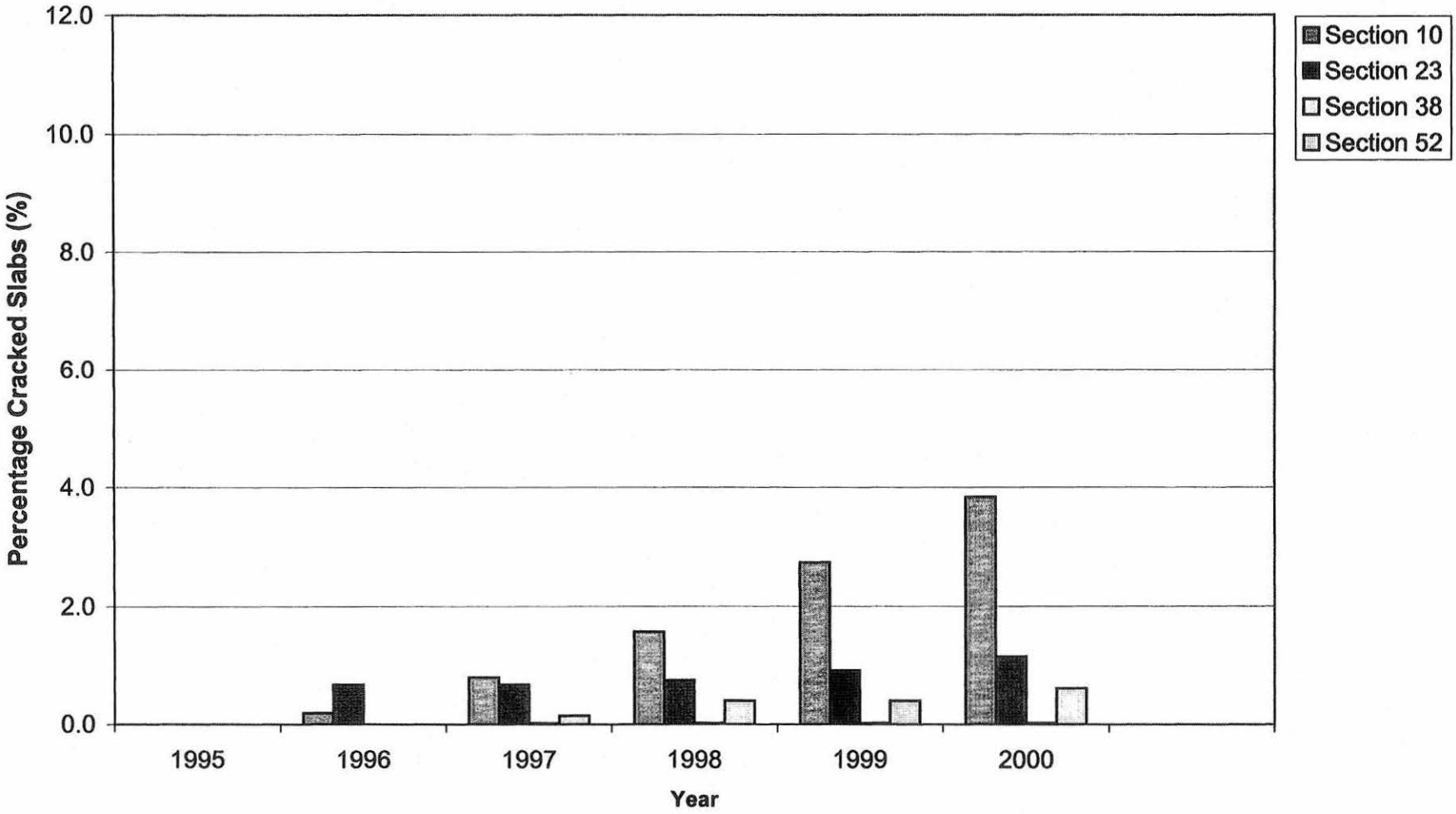
APPENDIX A

Visual Distress Testing

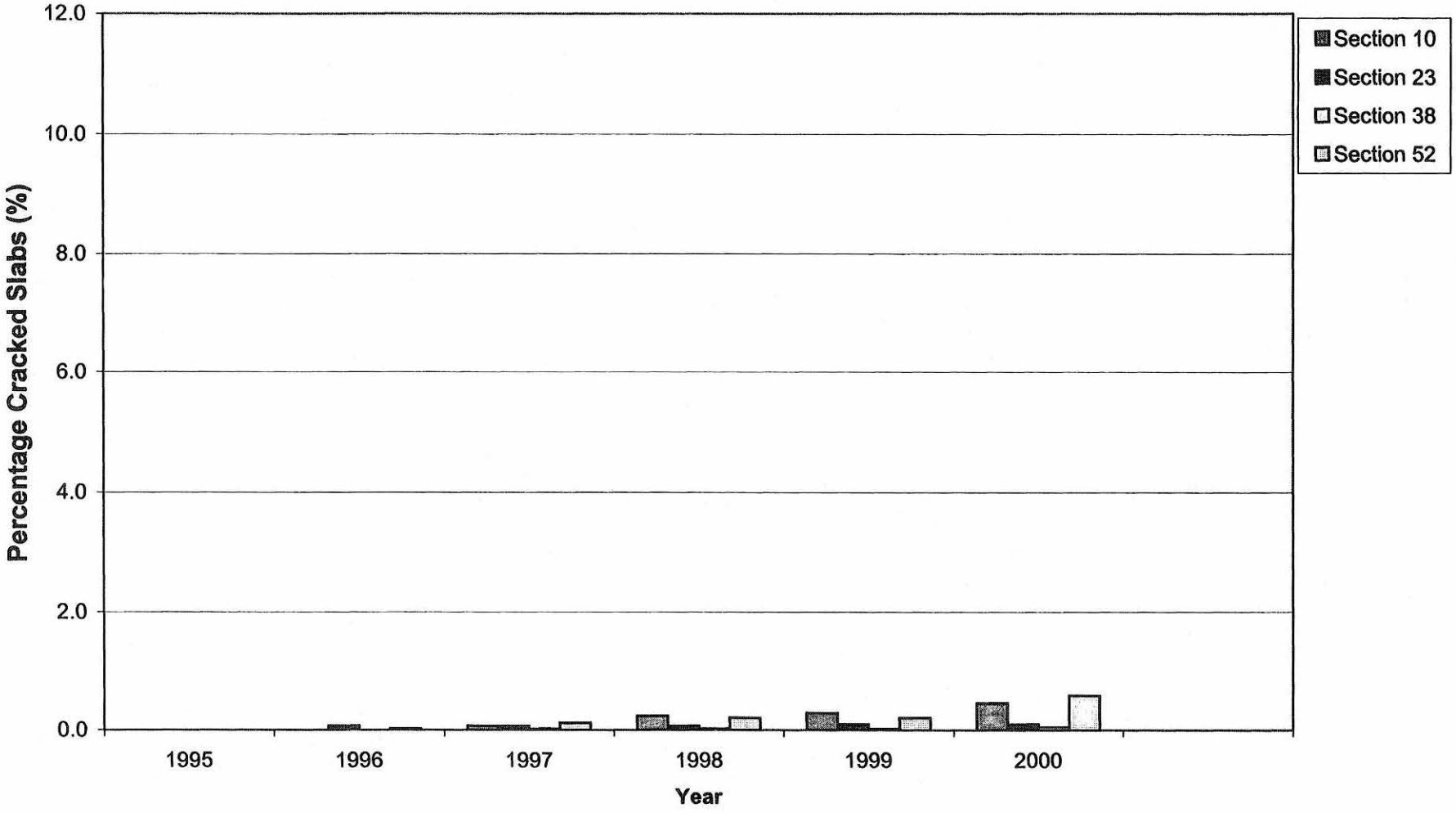
Transverse Cracks
2 in. Depth, 2 ft. Squares

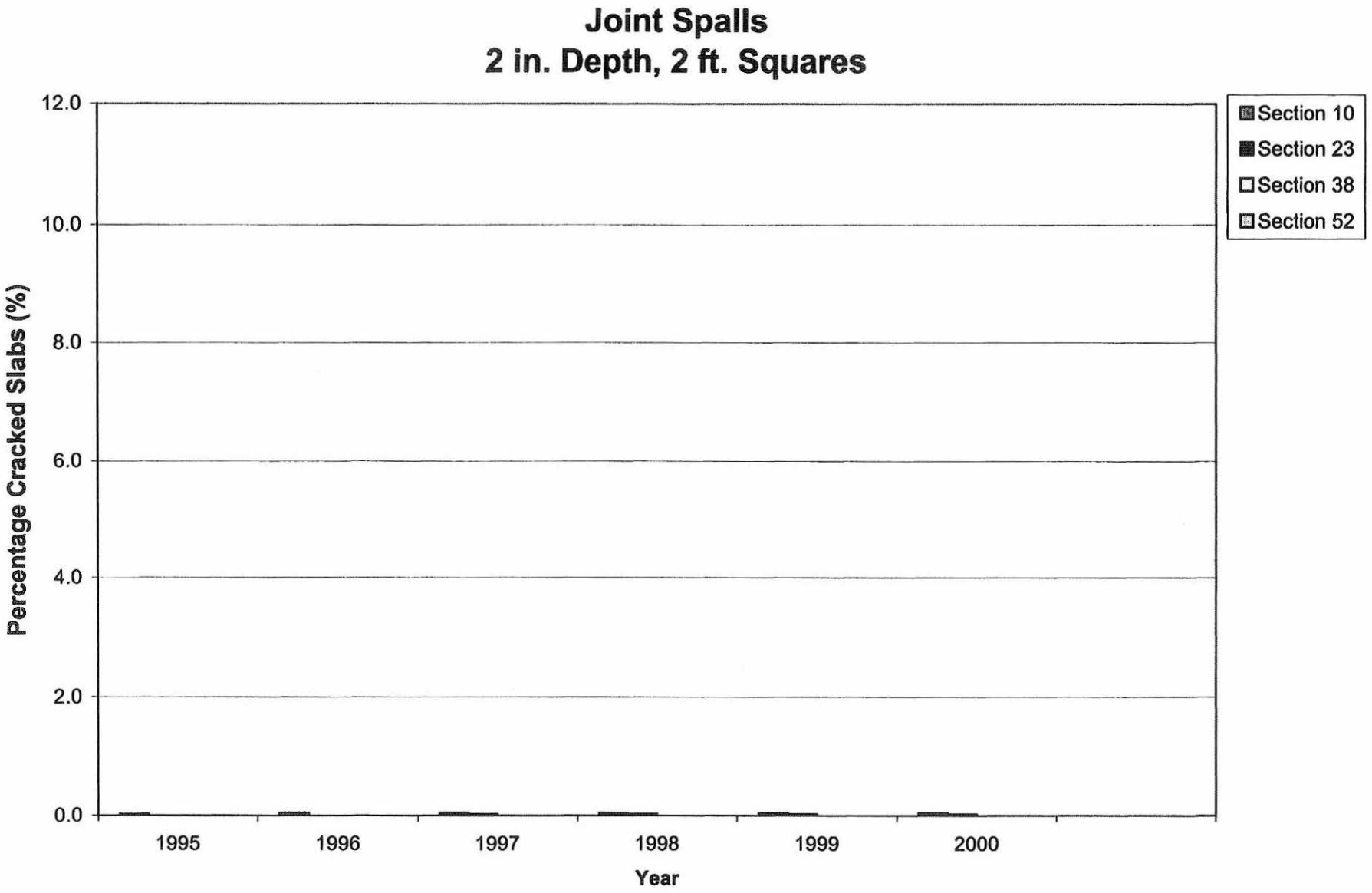


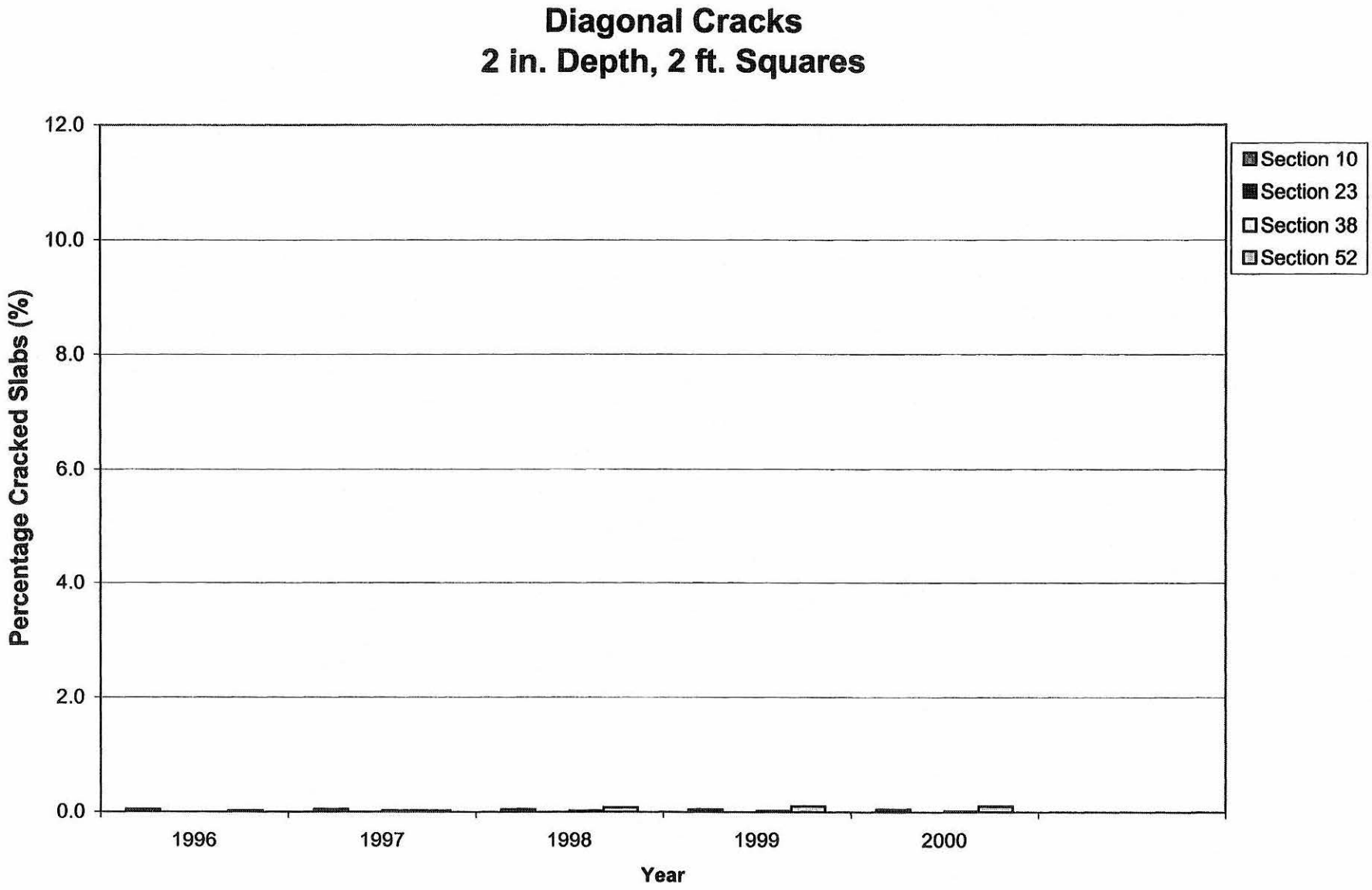
Longitudinal Cracks
2 in. Depth, 2 ft. Squares

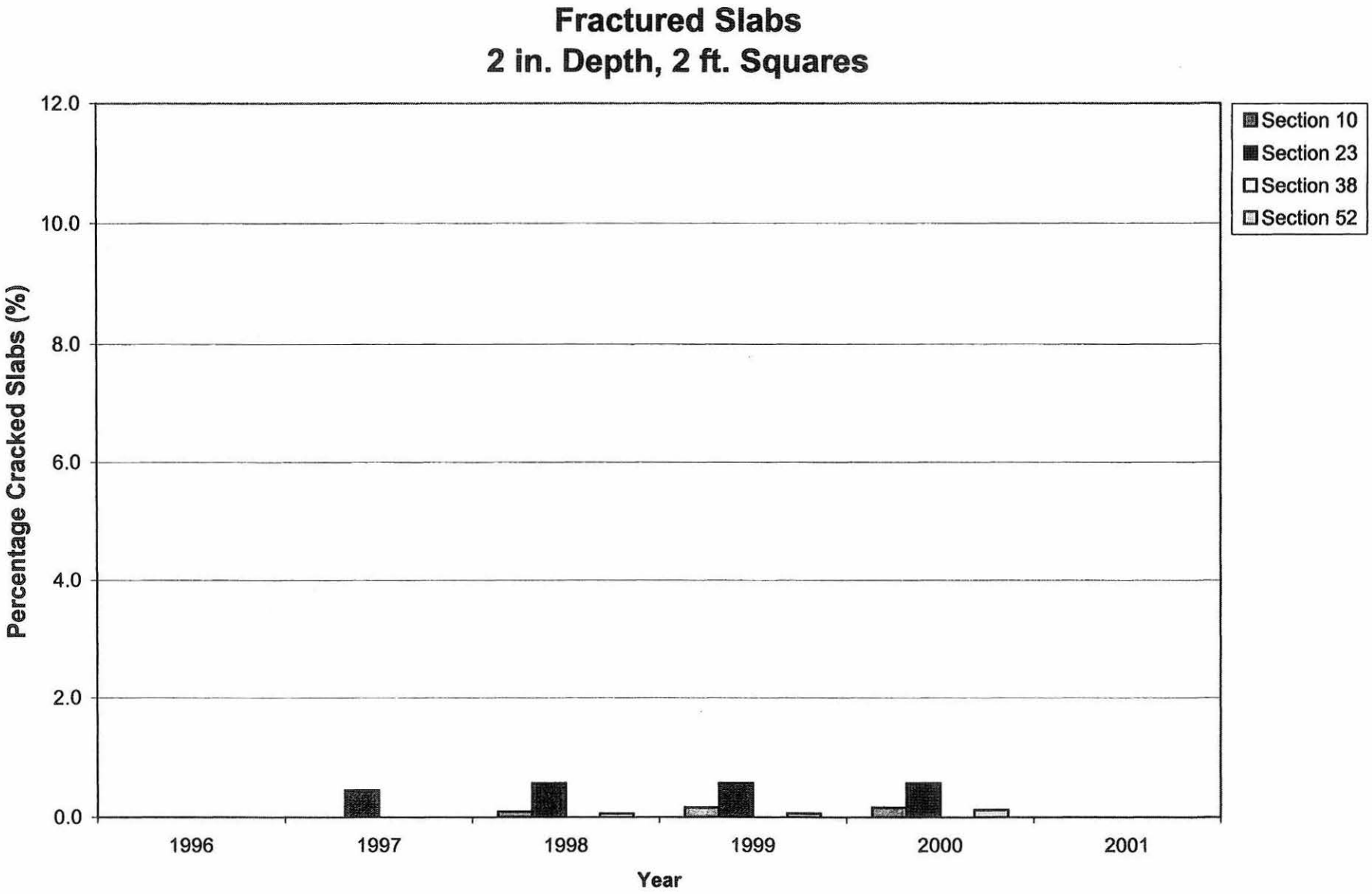


Corner Cracks
2 in. Depth, 2 ft. Squares

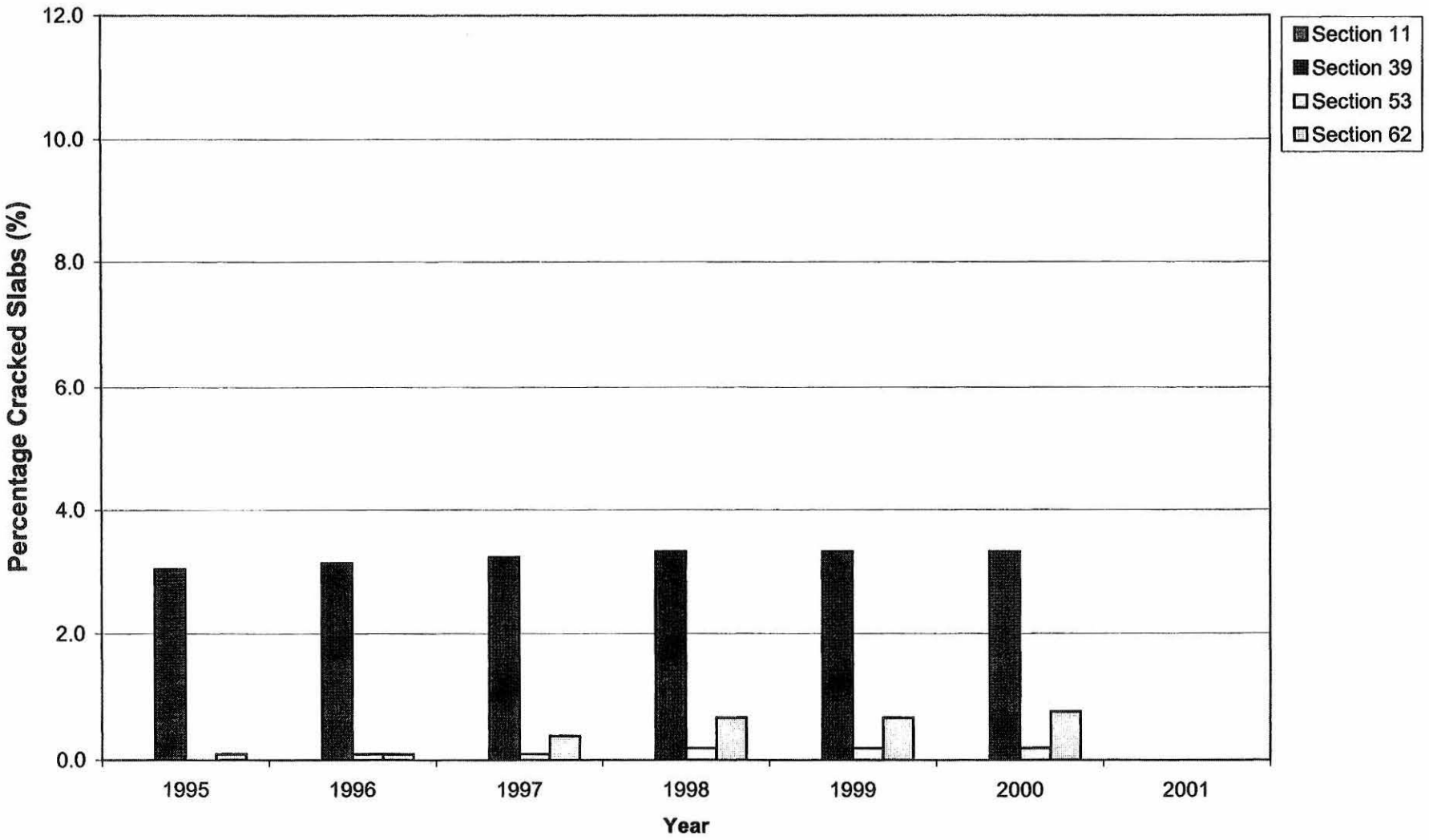


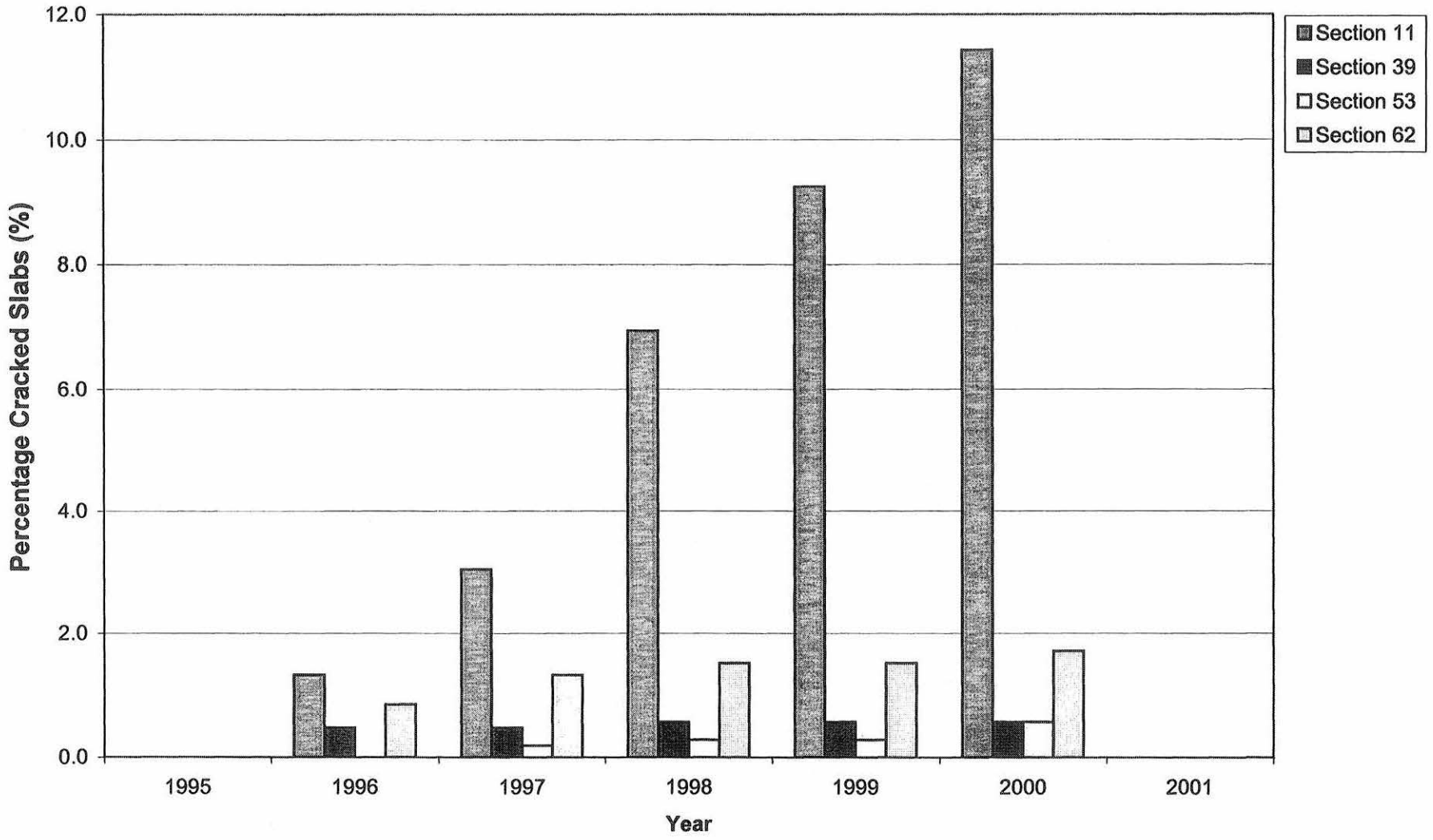

Joint Spalls
2 in. Depth, 2 ft. Squares
Percentage Cracked Slabs (%)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1995
1996
1997
1998
1999
2000
Year
Section 10
Section 23
Section 38
Section 52

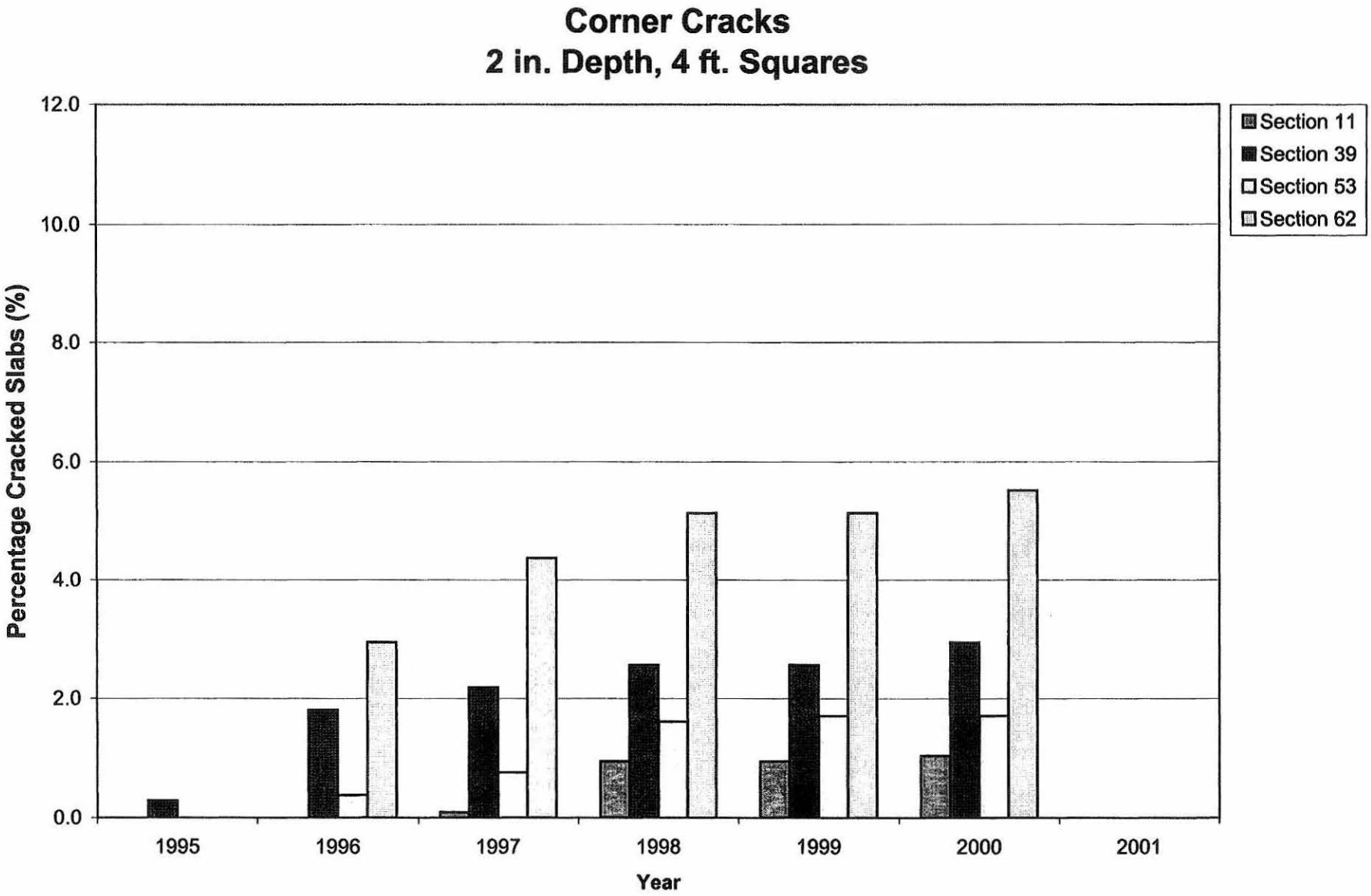

Diagonal Cracks
2 in. Depth, 2 ft. Squares
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Percentage Cracked Slabs (%)
1996
1997
1998
1999
2000
Year
Section 10
Section 23
Section 38
Section 52

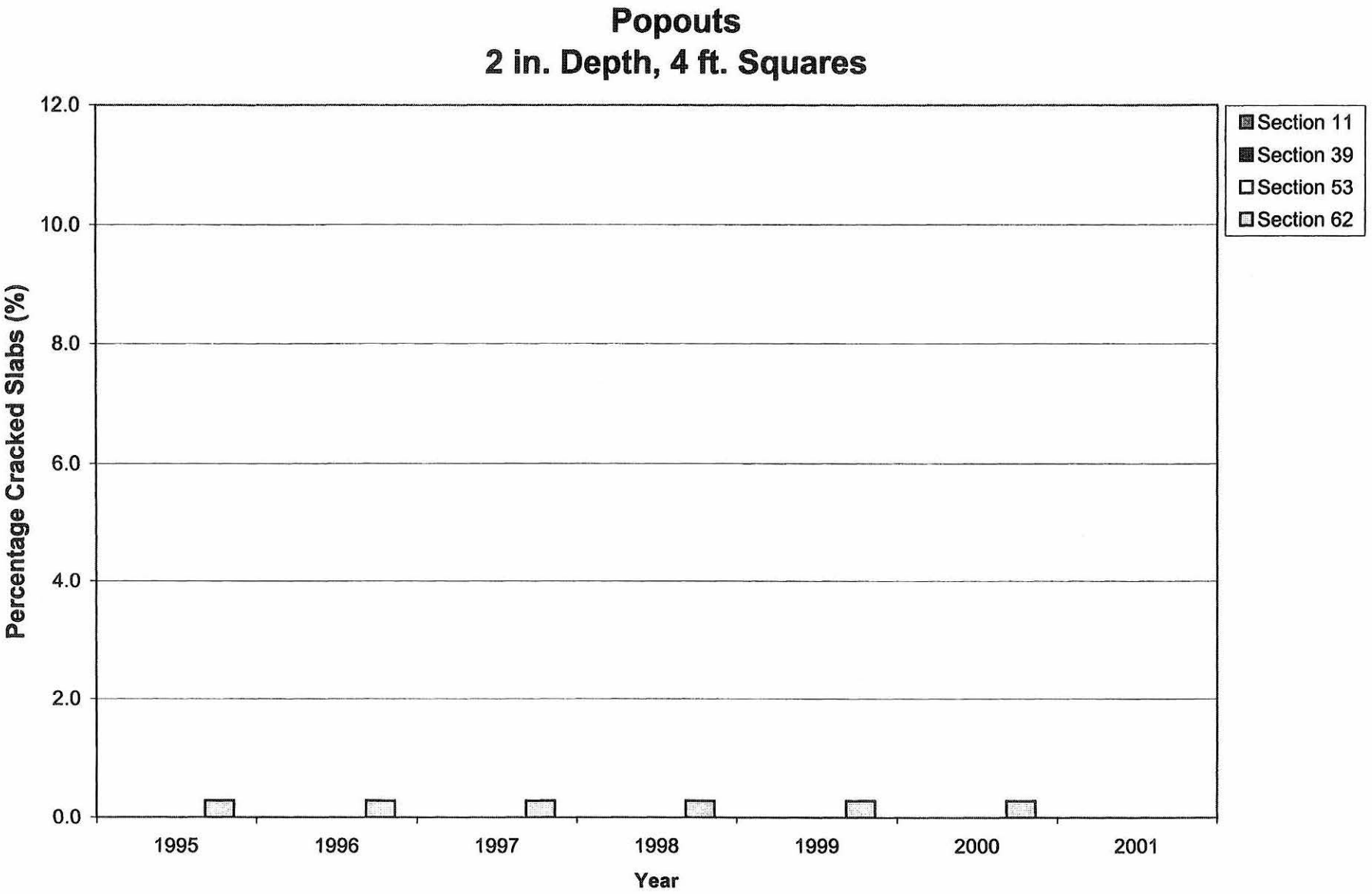

Fractured Slabs
2 in. Depth, 2 ft. Squares
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Percentage Cracked Slabs (%)
1996
1997
1998
1999
2000
2001
Year
Section 10
Section 23
Section 38
Section 52

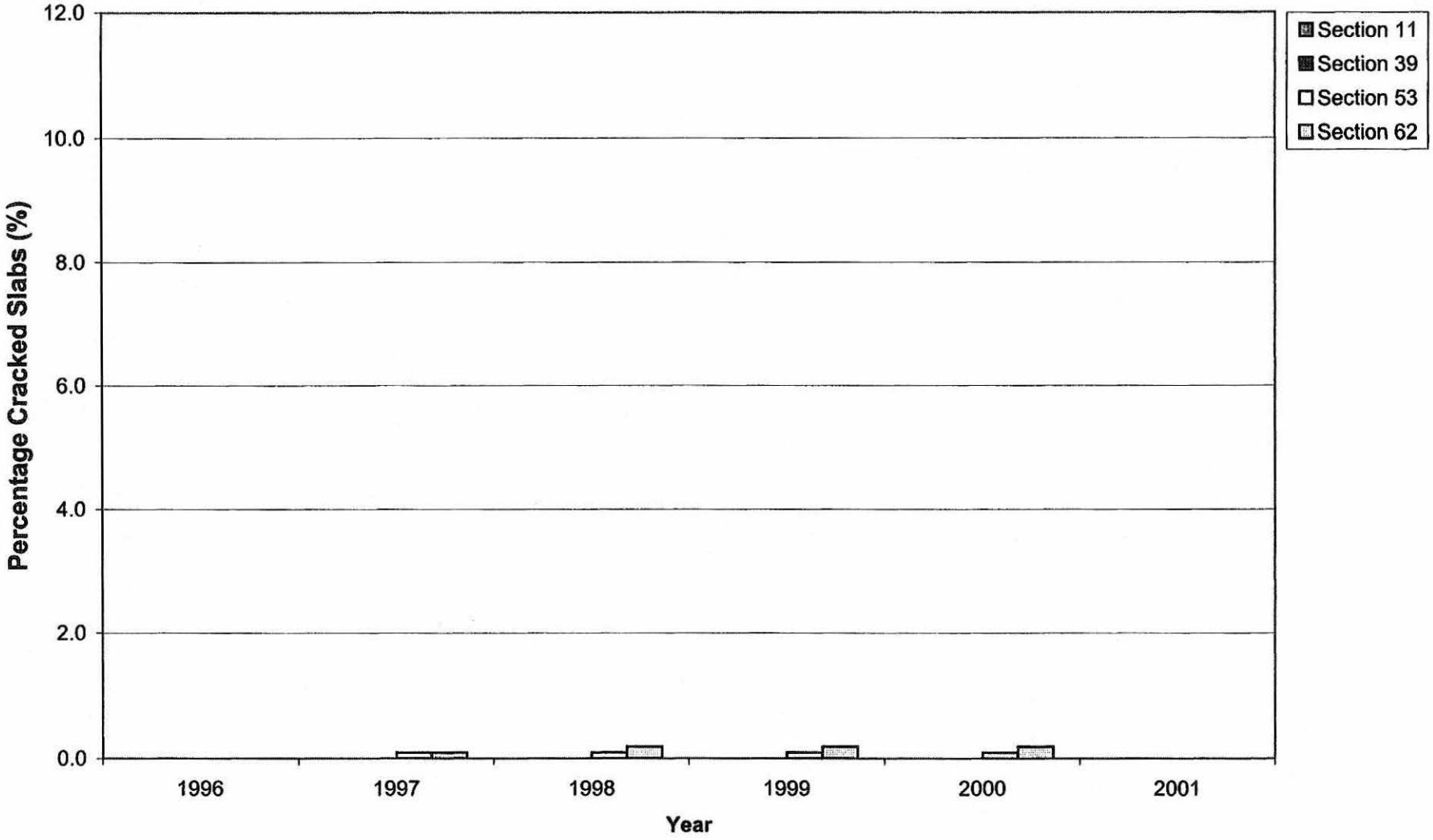
6-A


Transverse Cracks
2 in. Depth, 4 ft. Squares
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Percentage Cracked Slabs (%)
1995
1996
1997
1998
1999
2000
2001
Year
Section 11
Section 39
Section 53
Section 62

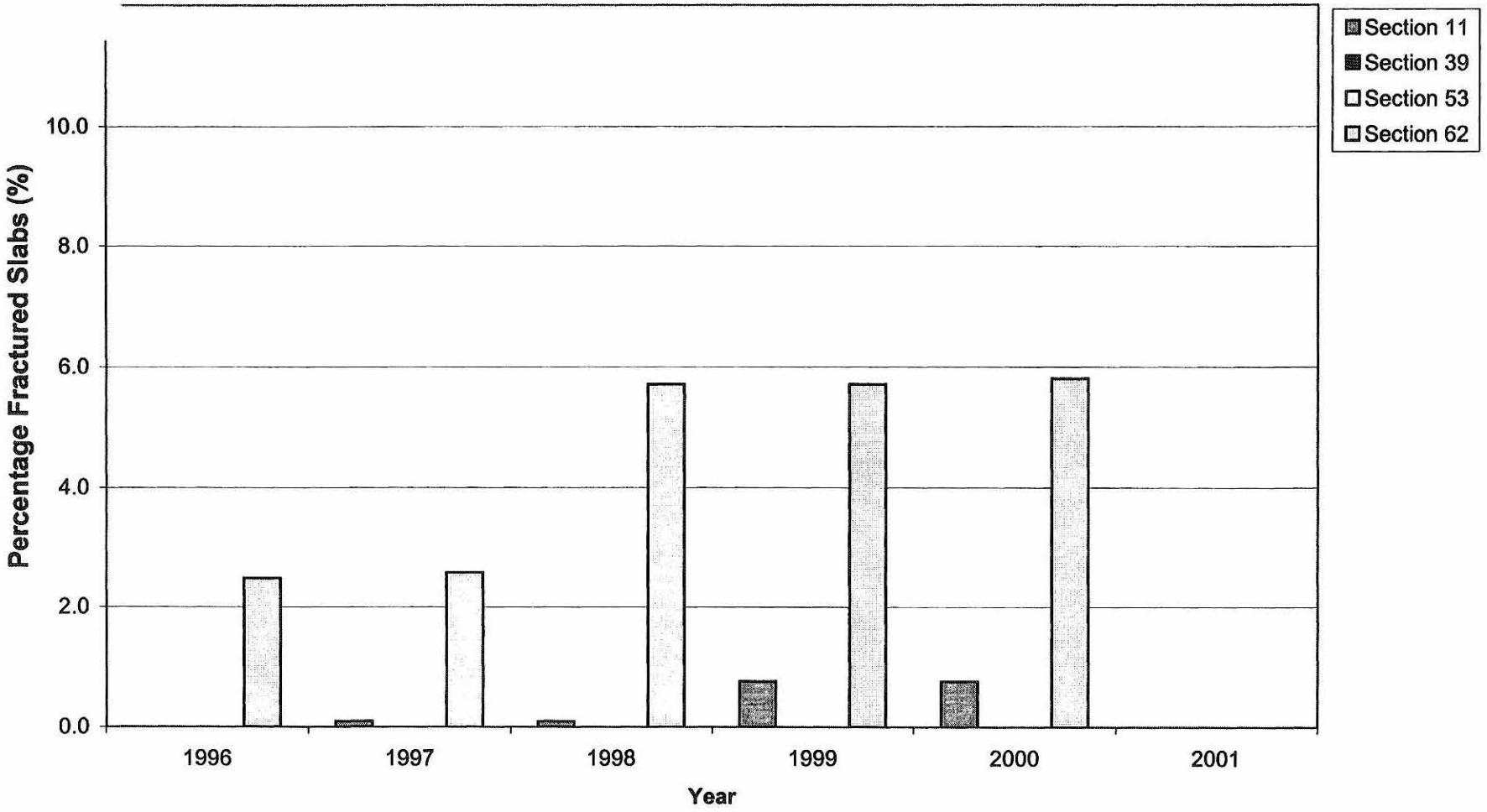

Longitudinal Cracks
2 in. Depth, 4 ft. Squares
Percentage Cracked Slabs (%)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1995
1996
1997
1998
1999
2000
2001
Year
Section 11
Section 39
Section 53
Section 62

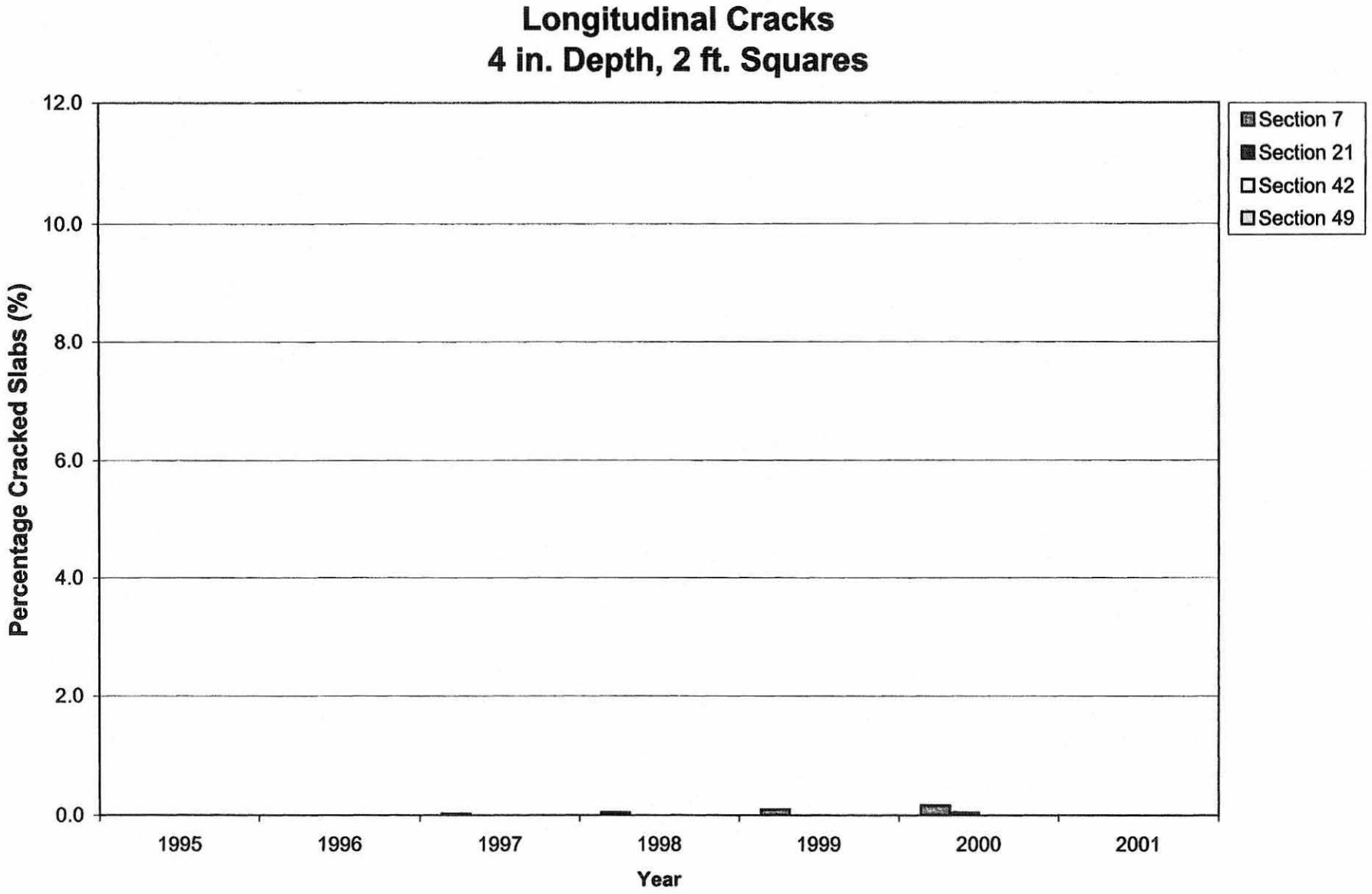

Corner Cracks
2 in. Depth, 4 ft. Squares
Percentage Cracked Slabs (%)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1995
1996
1997
1998
1999
2000
2001
Year
Section 11
Section 39
Section 53
Section 62

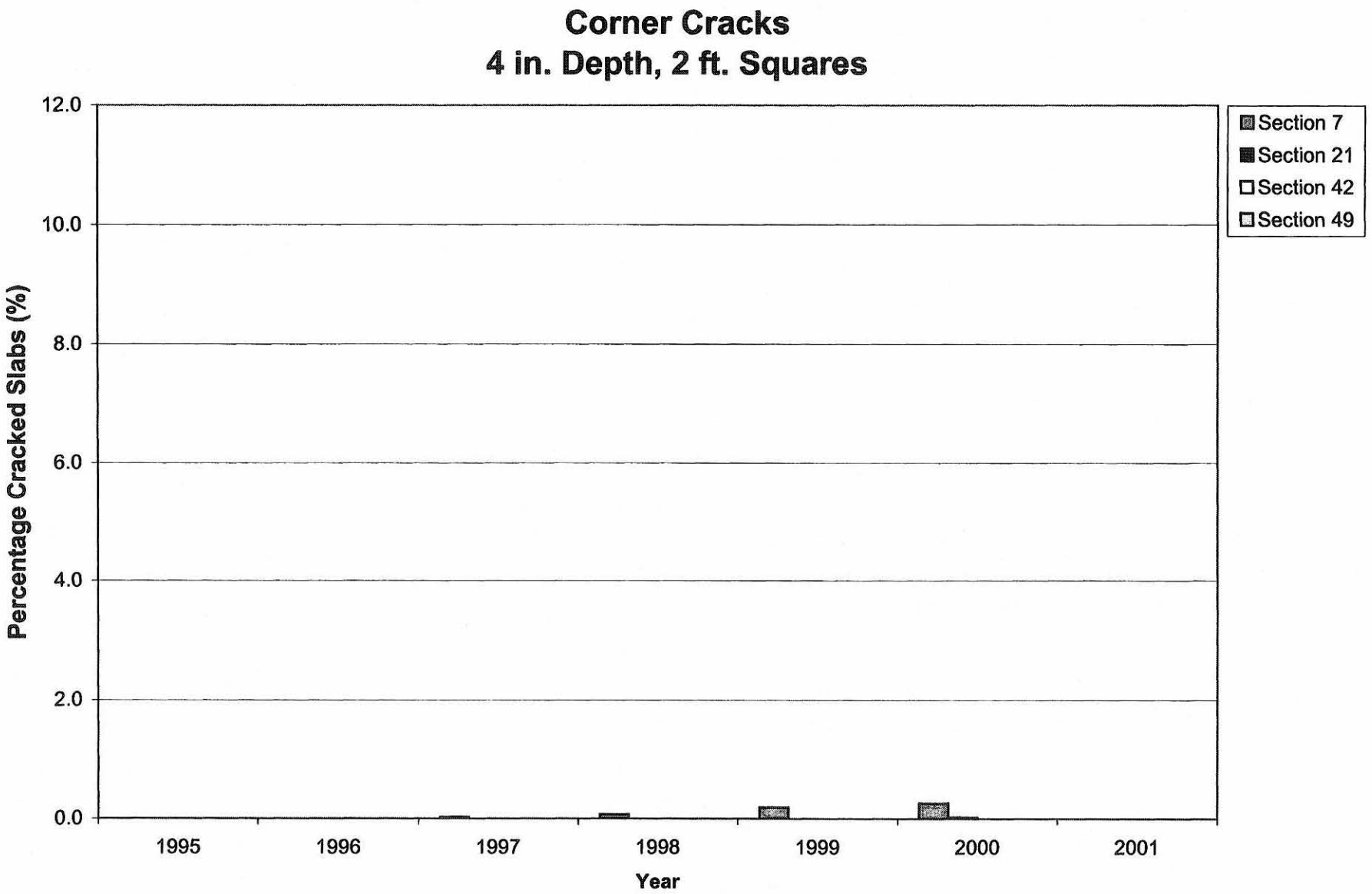

Popouts
2 in. Depth, 4 ft. Squares
Percentage Cracked Slabs (%)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1995
1996
1997
1998
1999
2000
2001
Year
Section 11
Section 39
Section 53
Section 62

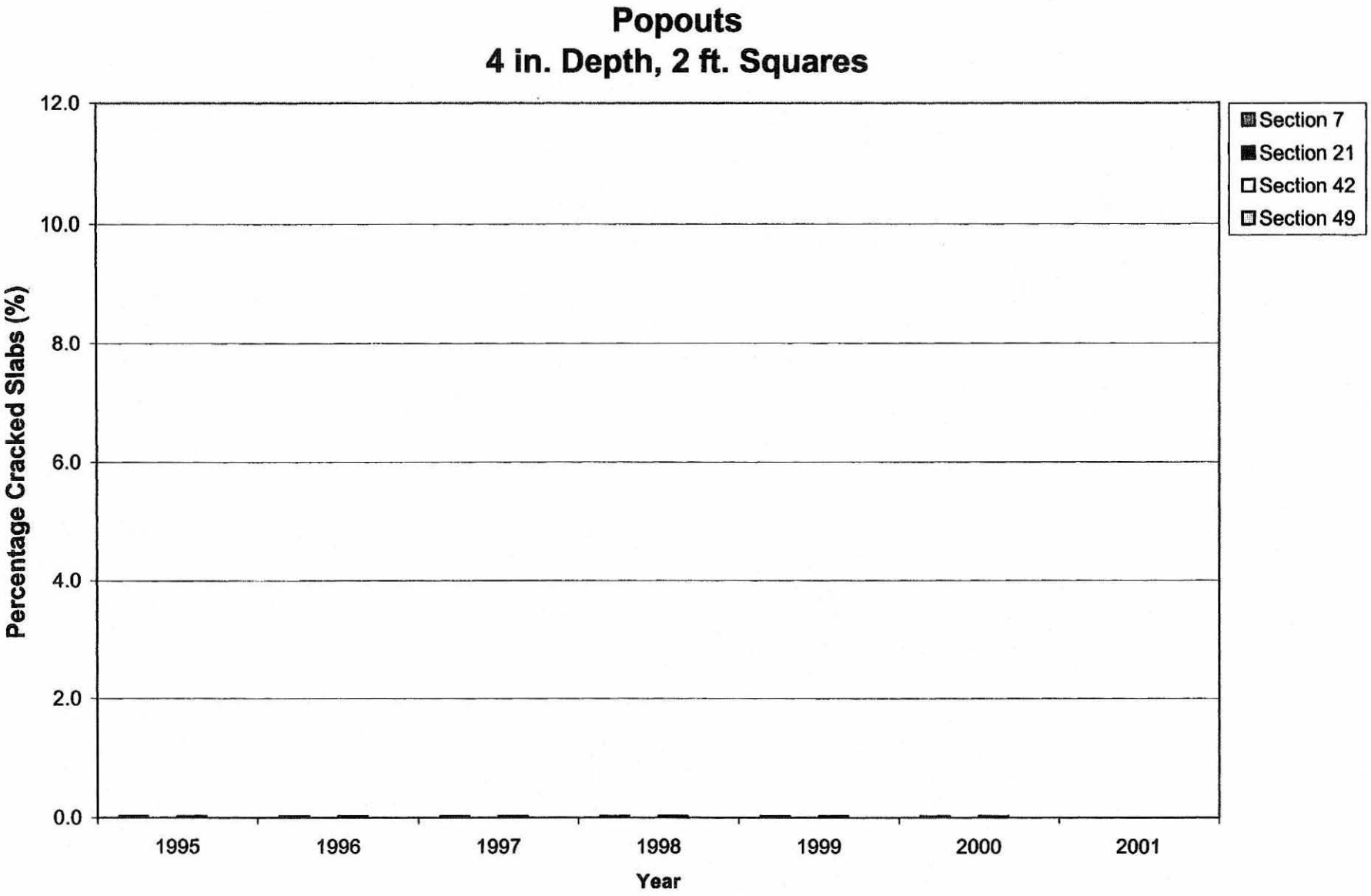

Diagonal Cracks
2 in. Depth, 4 ft. Squares
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Percentage Cracked Slabs (%)
1996
1997
1998
1999
2000
2001
Year
Section 11
Section 39
Section 53
Section 62

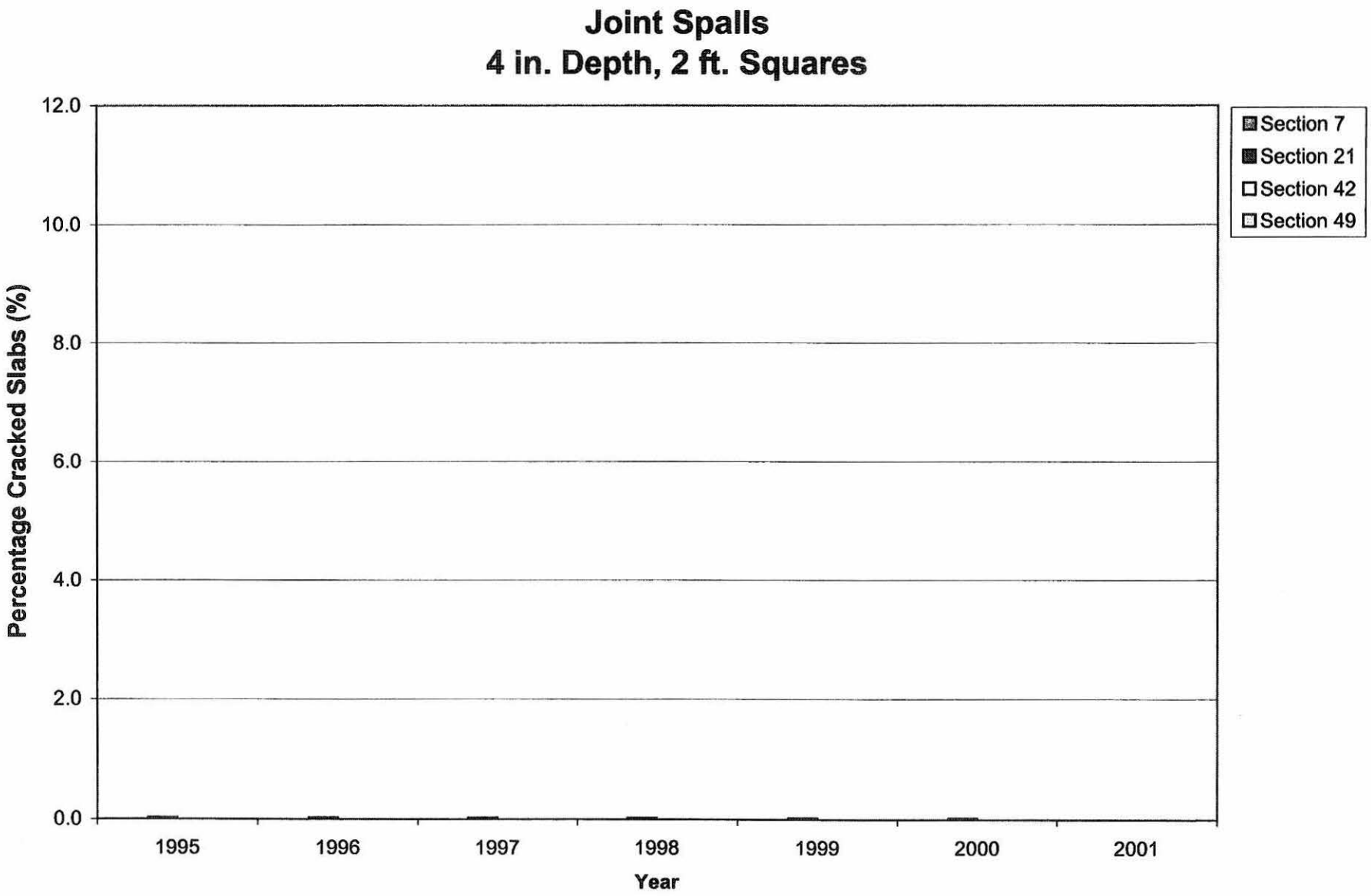
Fractured Slabs
2 in. Depth, 4 ft. Squares

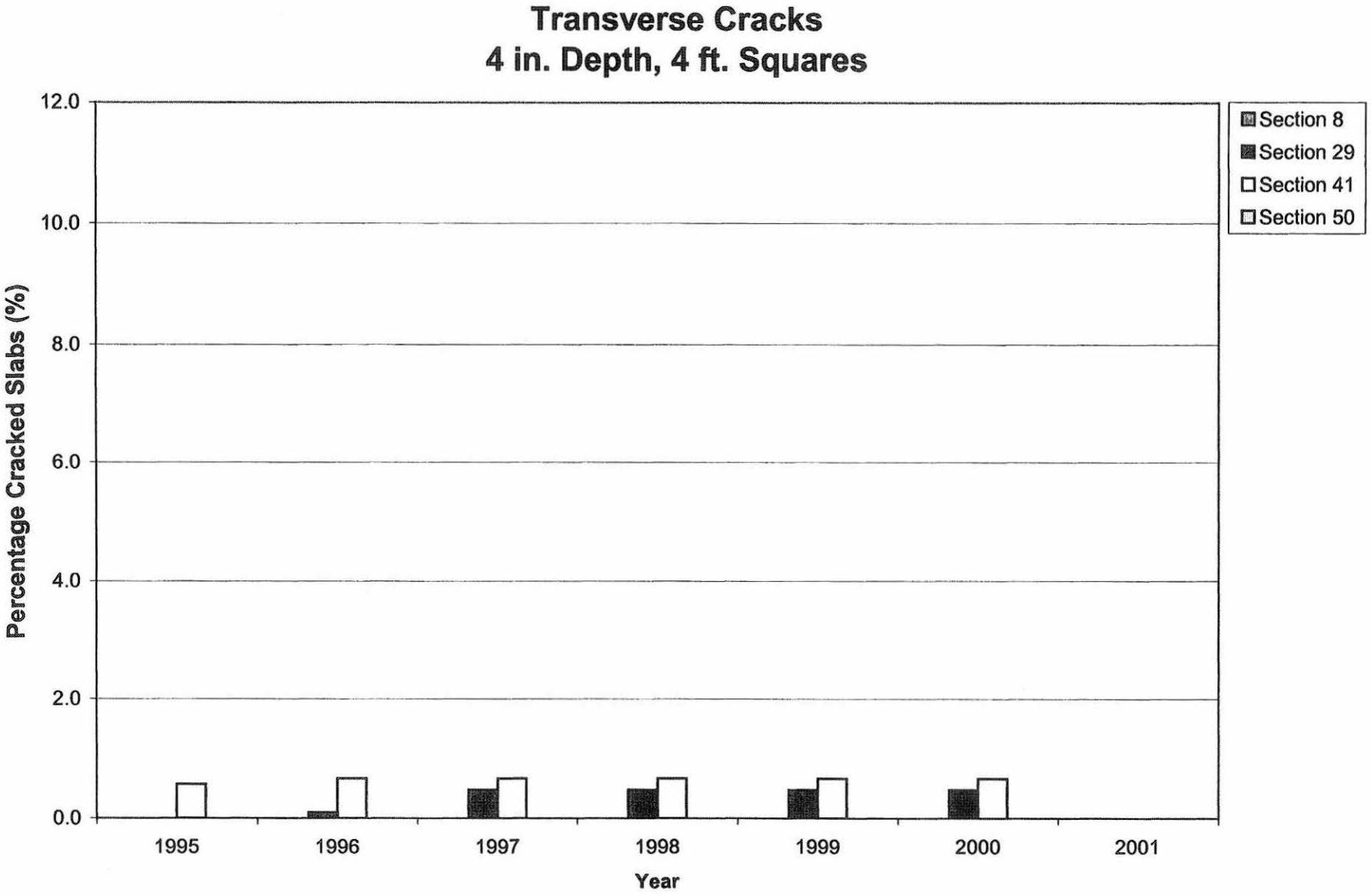


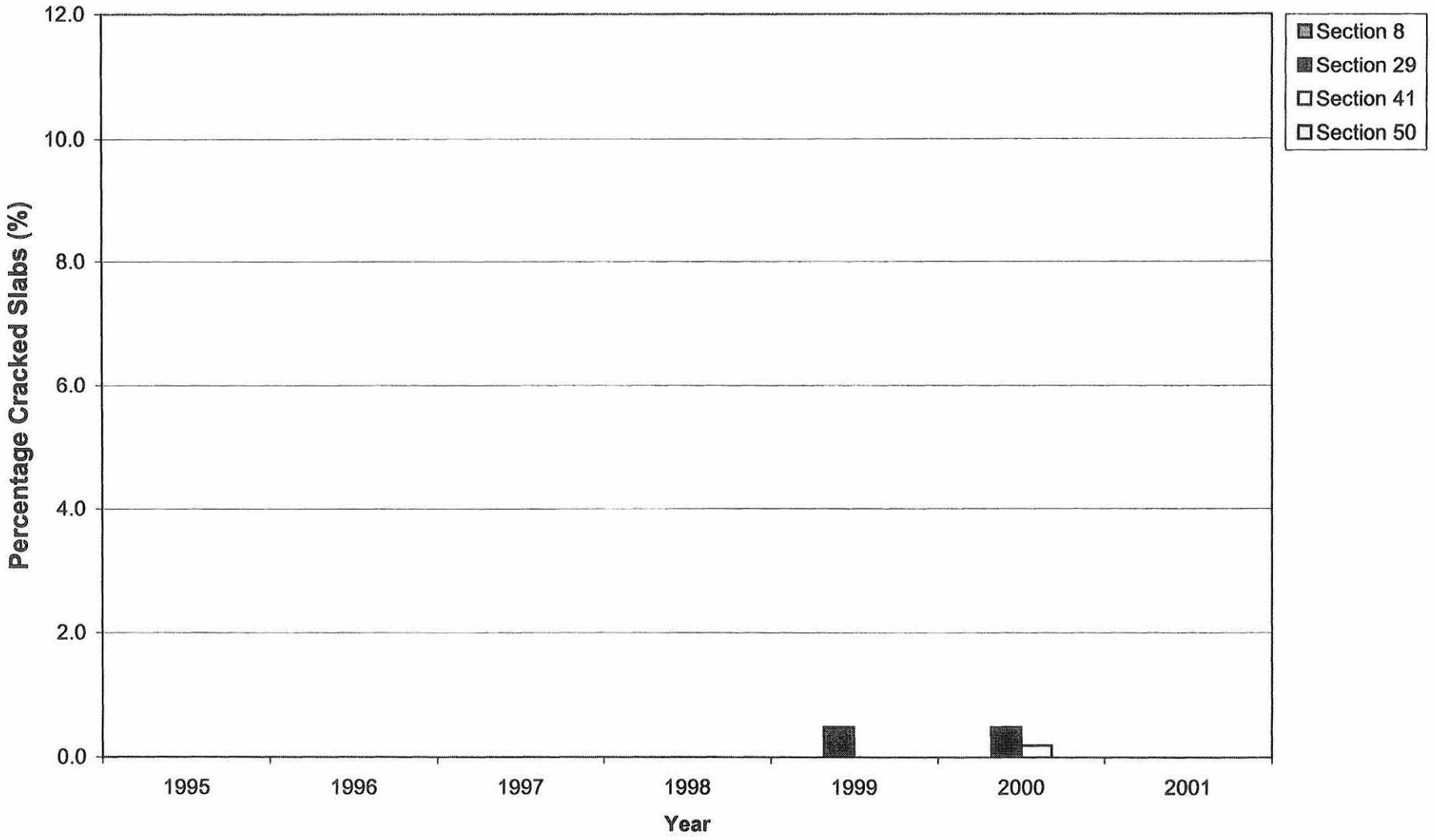

Longitudinal Cracks
4 in. Depth, 2 ft. Squares
Percentage Cracked Slabs (%)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1995
1996
1997
1998
1999
2000
2001
Year
Section 7
Section 21
Section 42
Section 49

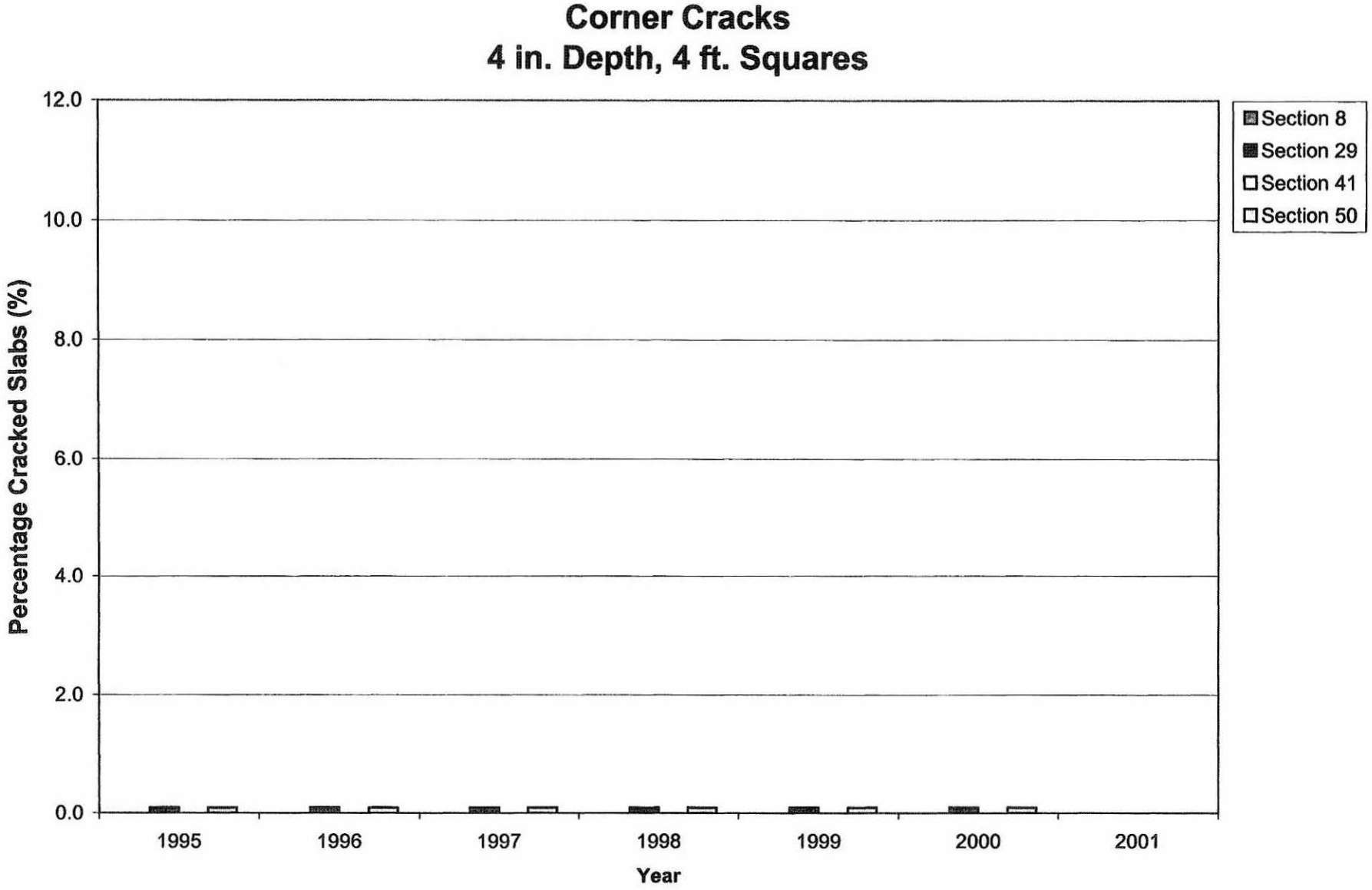

Corner Cracks
4 in. Depth, 2 ft. Squares
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Percentage Cracked Slabs (%)
1995
1996
1997
1998
1999
2000
2001
Year
Section 7
Section 21
Section 42
Section 49

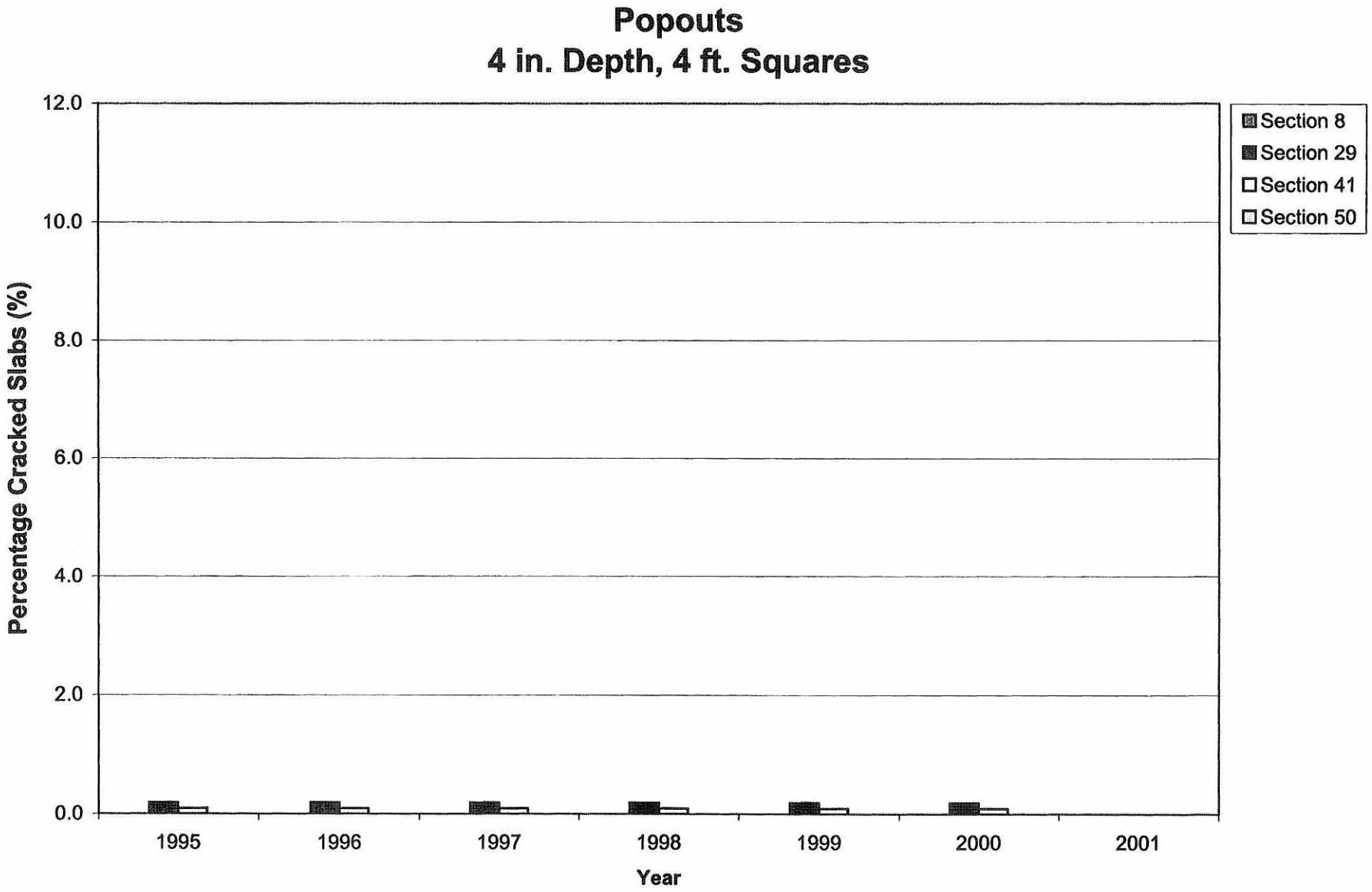

Popouts
4 in. Depth, 2 ft. Squares
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Percentage Cracked Slabs (%)
1995
1996
1997
1998
1999
2000
2001
Year
Section 7
Section 21
Section 42
Section 49

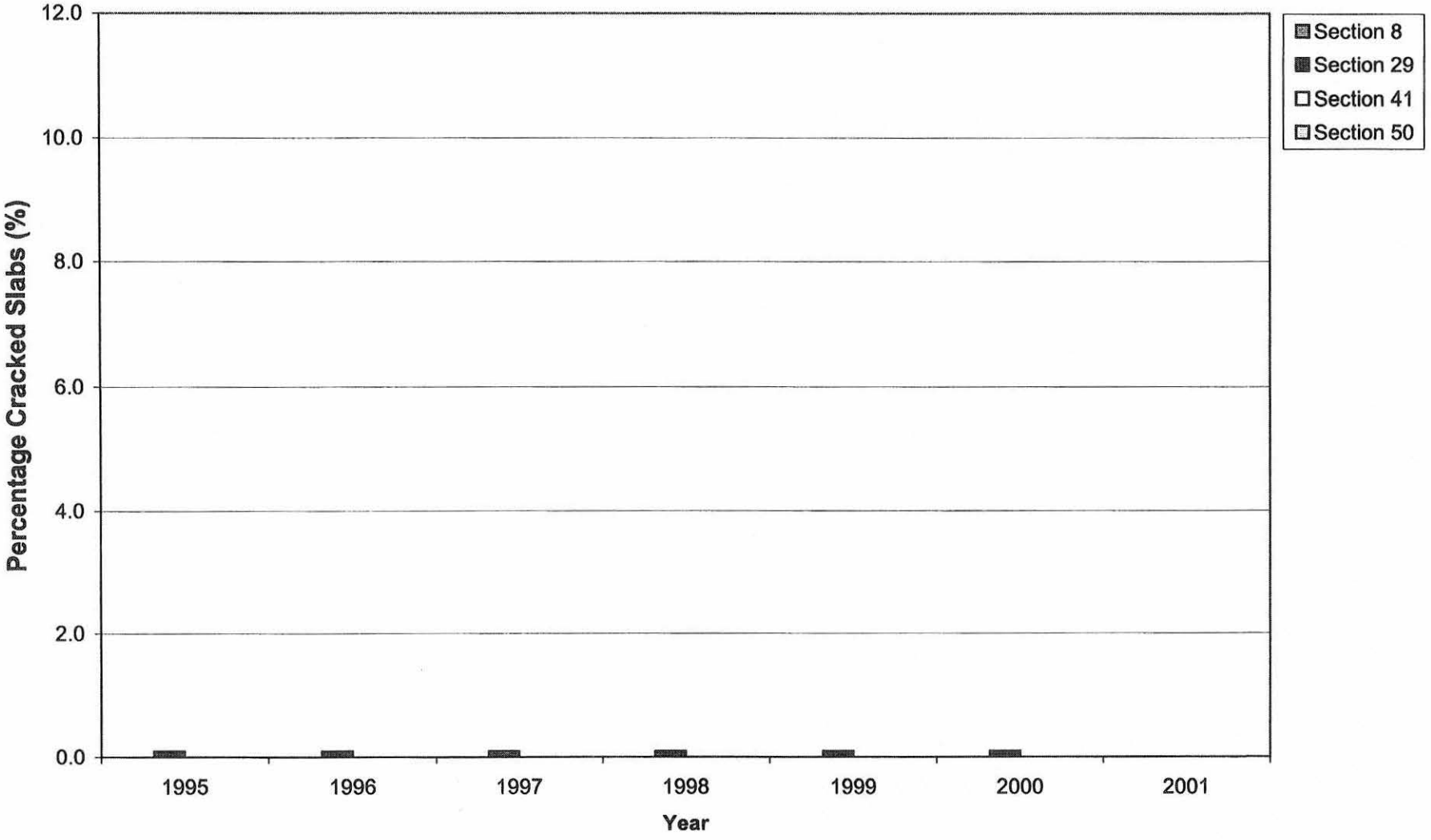

Joint Spalls
4 in. Depth, 2 ft. Squares
Percentage Cracked Slabs (%)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1995
1996
1997
1998
1999
2000
2001
Year
Section 7
Section 21
Section 42
Section 49

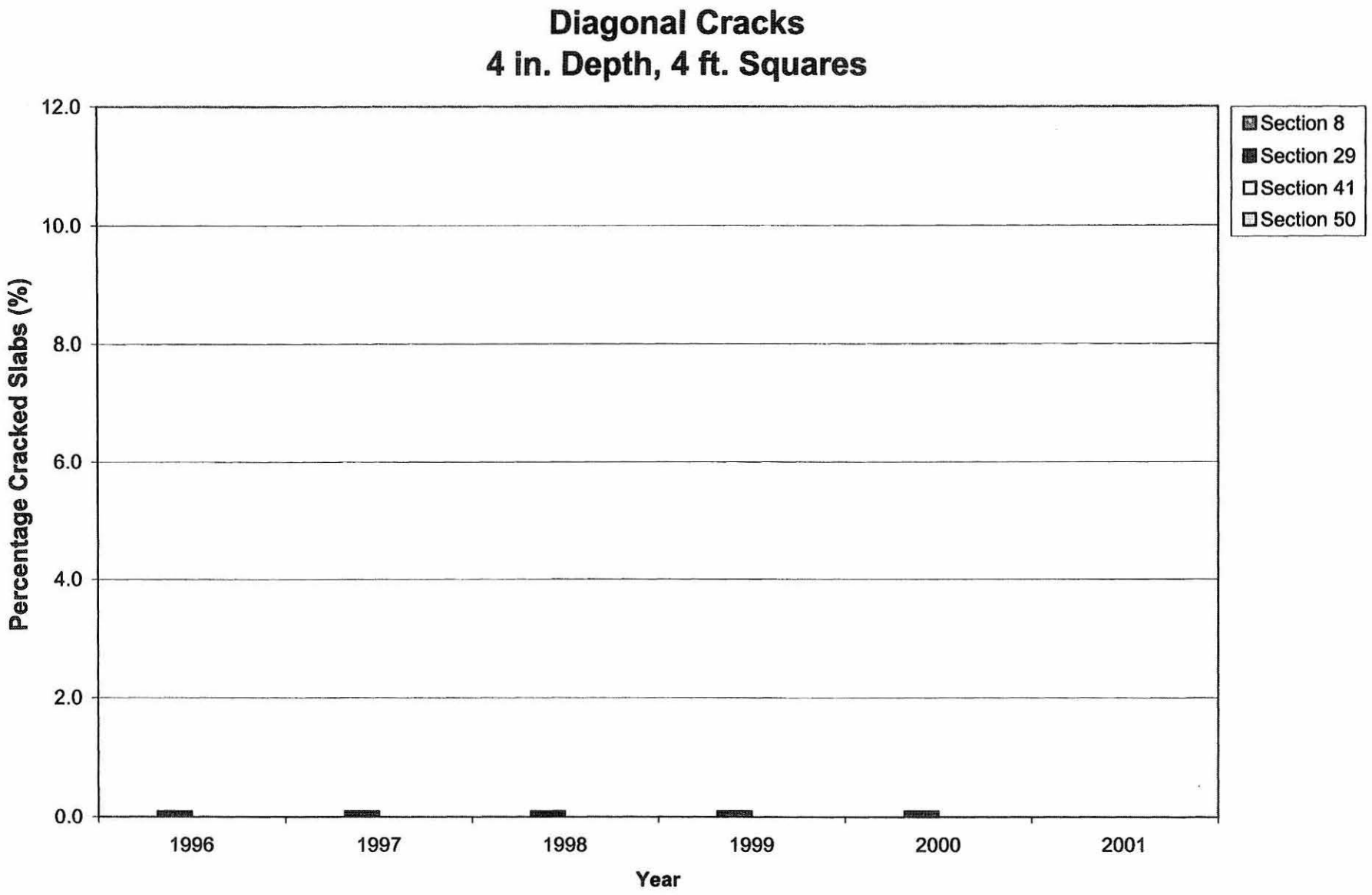

Transverse Cracks
4 in. Depth, 4 ft. Squares
Percentage Cracked Slabs (%)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1995
1996
1997
1998
1999
2000
2001
Year
Section 8
Section 29
Section 41
Section 50

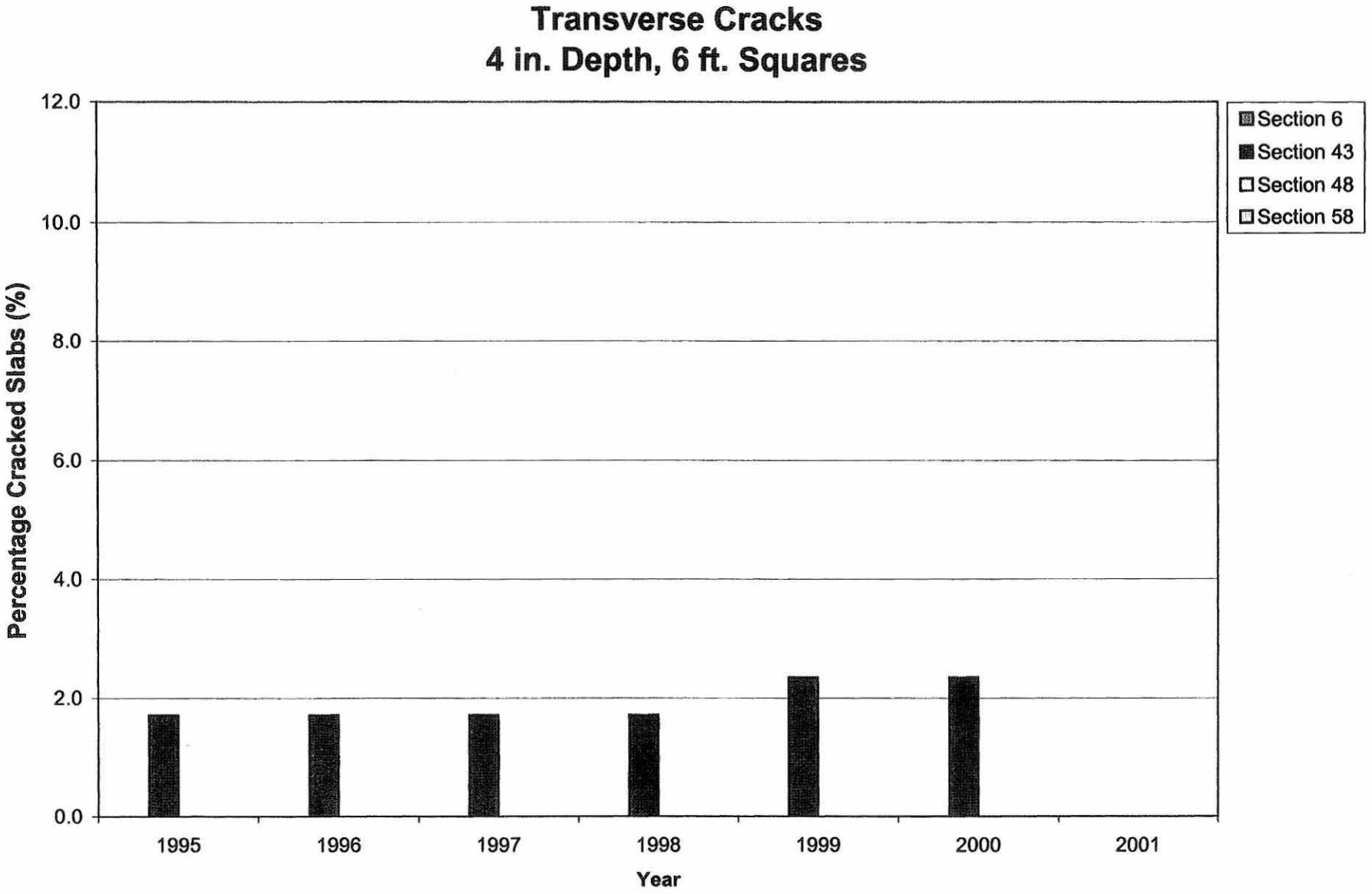

Longitudinal Cracks
4 in. Depth, 4 ft. Squares
Percentage Cracked Slabs (%)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1995
1996
1997
1998
1999
2000
2001
Year
Section 8
Section 29
Section 41
Section 50

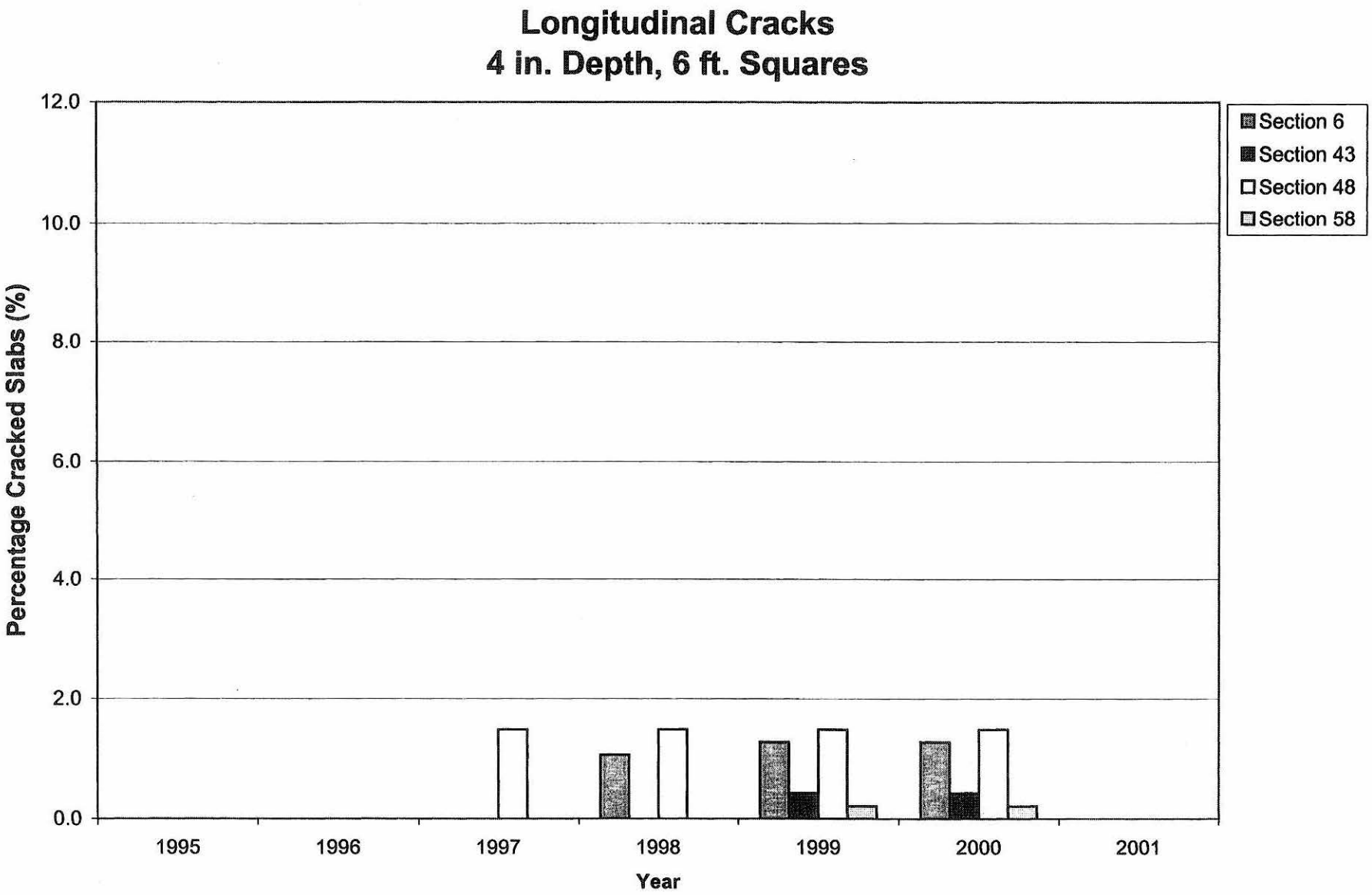

Corner Cracks
4 in. Depth, 4 ft. Squares
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Percentage Cracked Slabs (%)
1995
1996
1997
1998
1999
2000
2001
Year
Section 8
Section 29
Section 41
Section 50

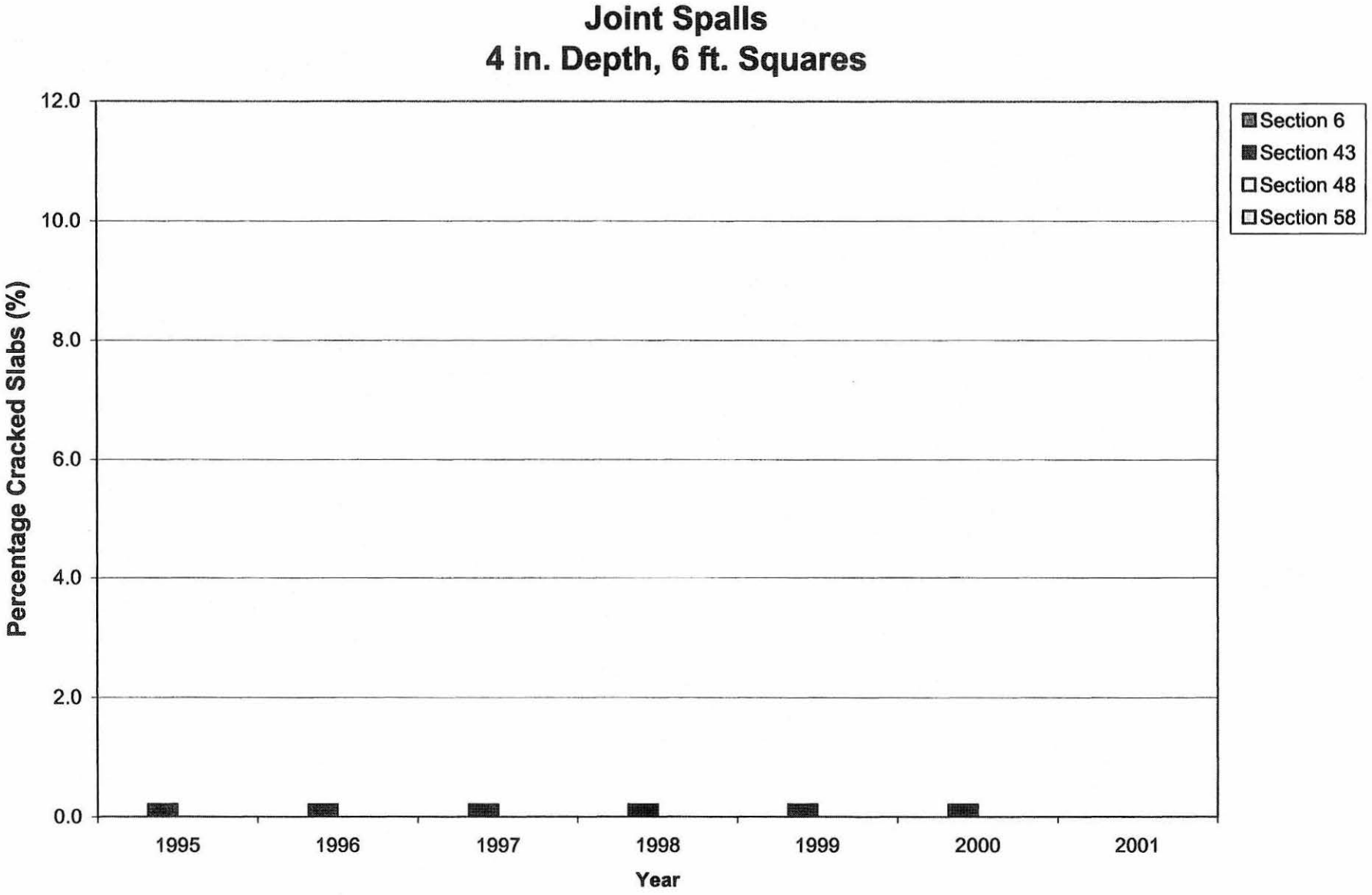

Popouts
4 in. Depth, 4 ft. Squares
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Percentage Cracked Slabs (%)
1995
1996
1997
1998
1999
2000
2001
Year
Section 8
Section 29
Section 41
Section 50

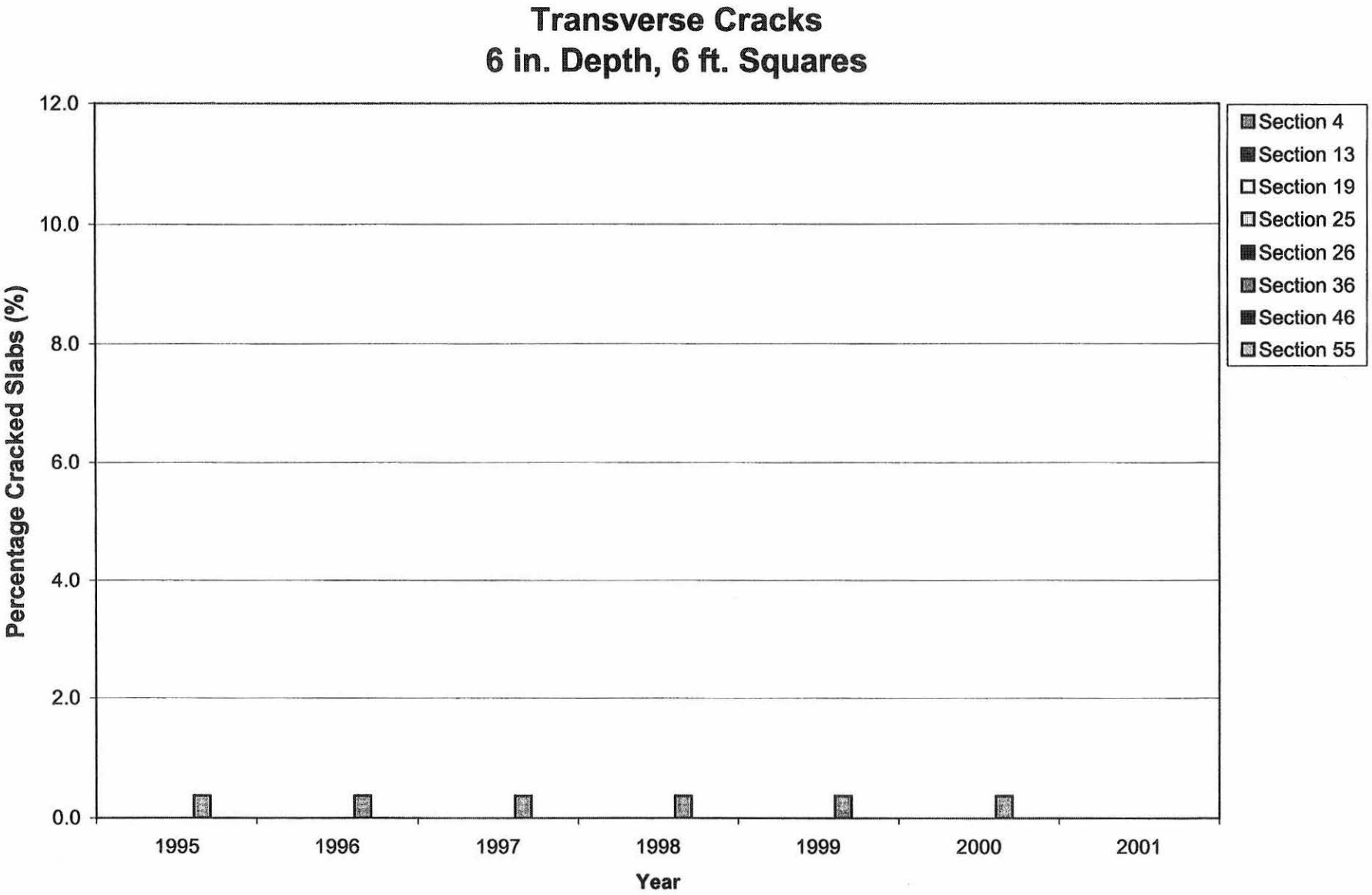

Joint Spalls
4 in. Depth, 4 ft. Squares
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Percentage Cracked Slabs (%)
1995
1996
1997
1998
1999
2000
2001
Year
Section 8
Section 29
Section 41
Section 50

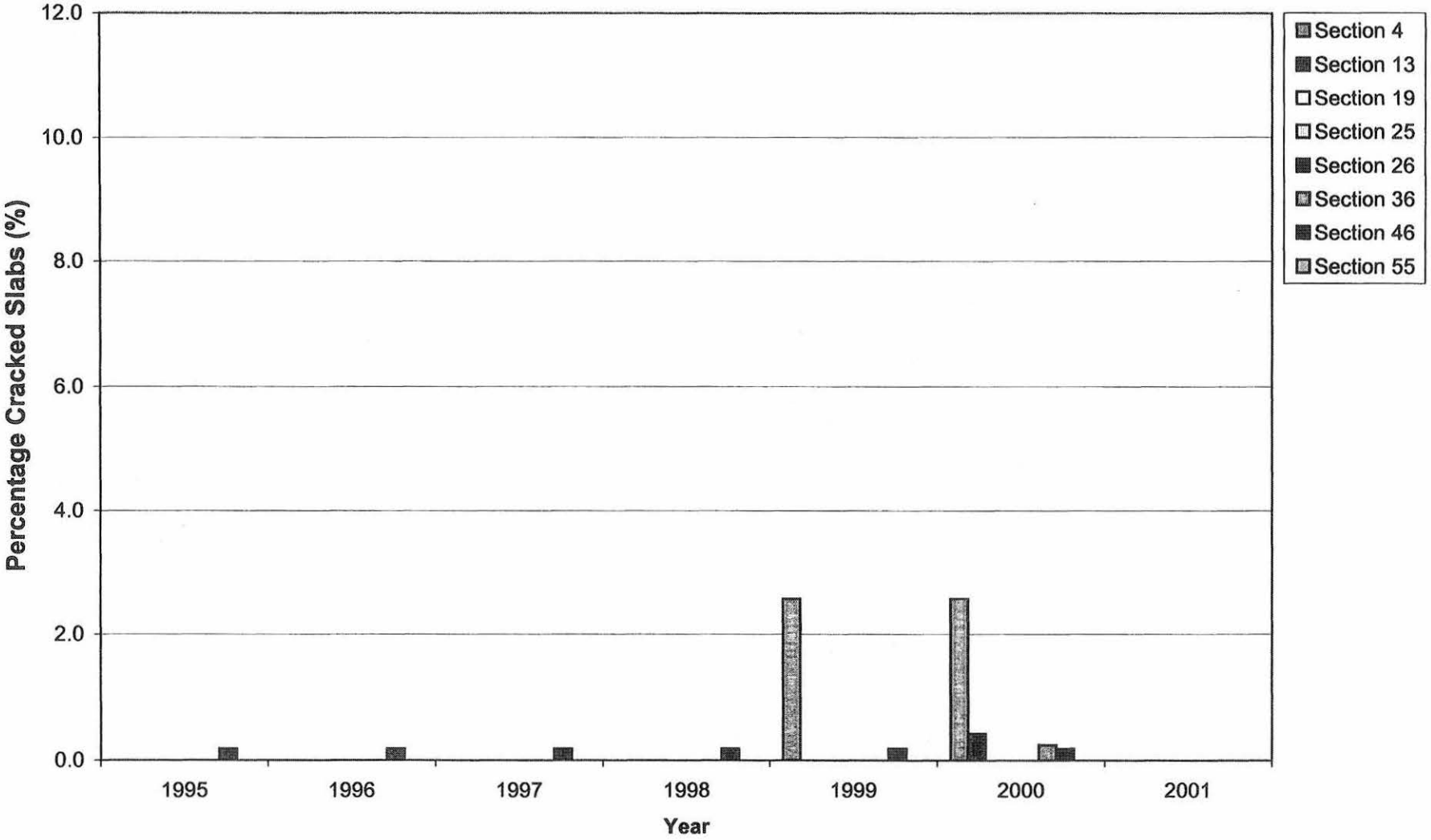

Diagonal Cracks
4 in. Depth, 4 ft. Squares
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Percentage Cracked Slabs (%)
1996
1997
1998
1999
2000
2001
Year
Section 8
Section 29
Section 41
Section 50

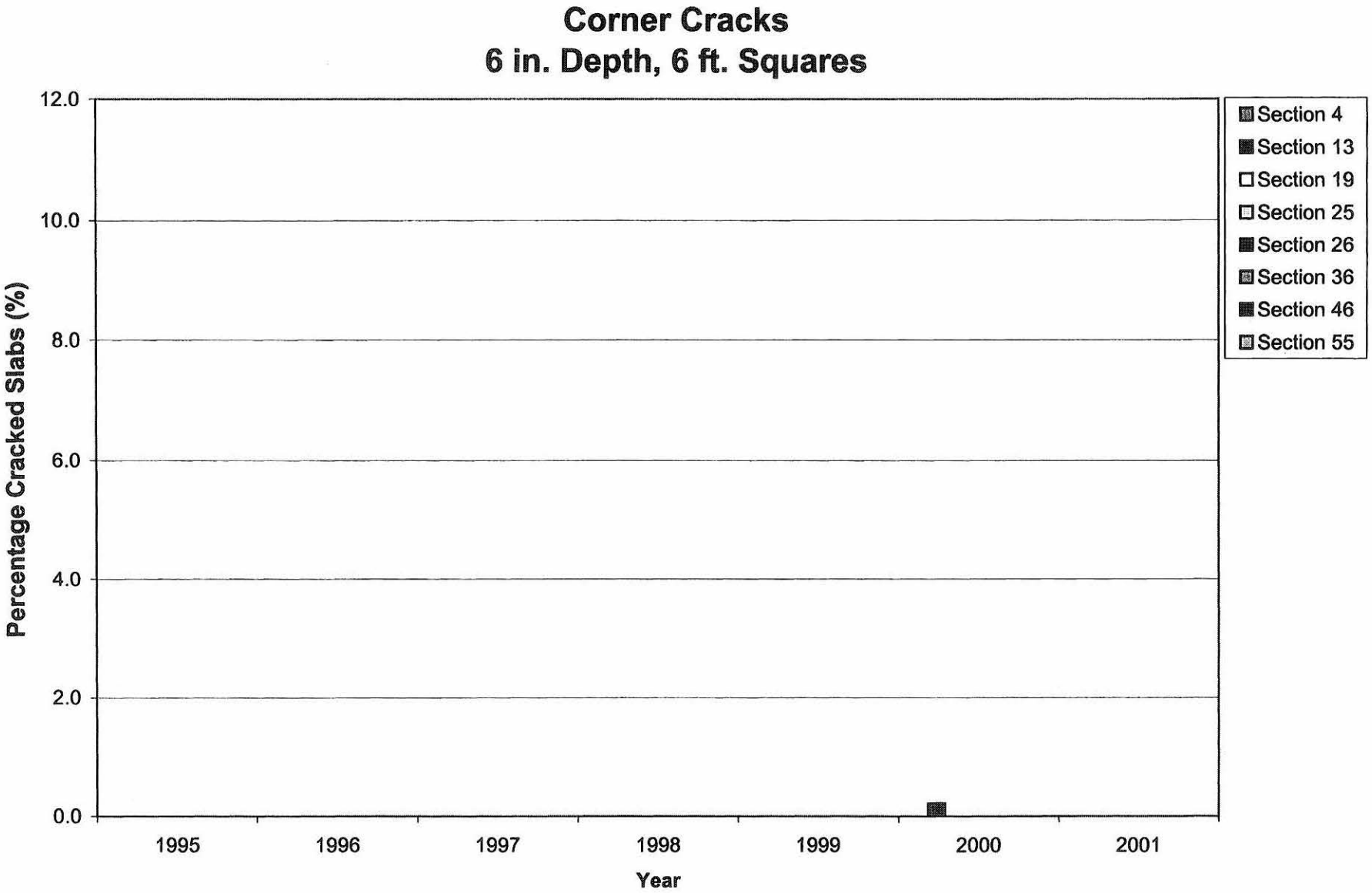

Transverse Cracks
4 in. Depth, 6 ft. Squares
Percentage Cracked Slabs (%)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1995
1996
1997
1998
1999
2000
2001
Year
Section 6
Section 43
Section 48
Section 58

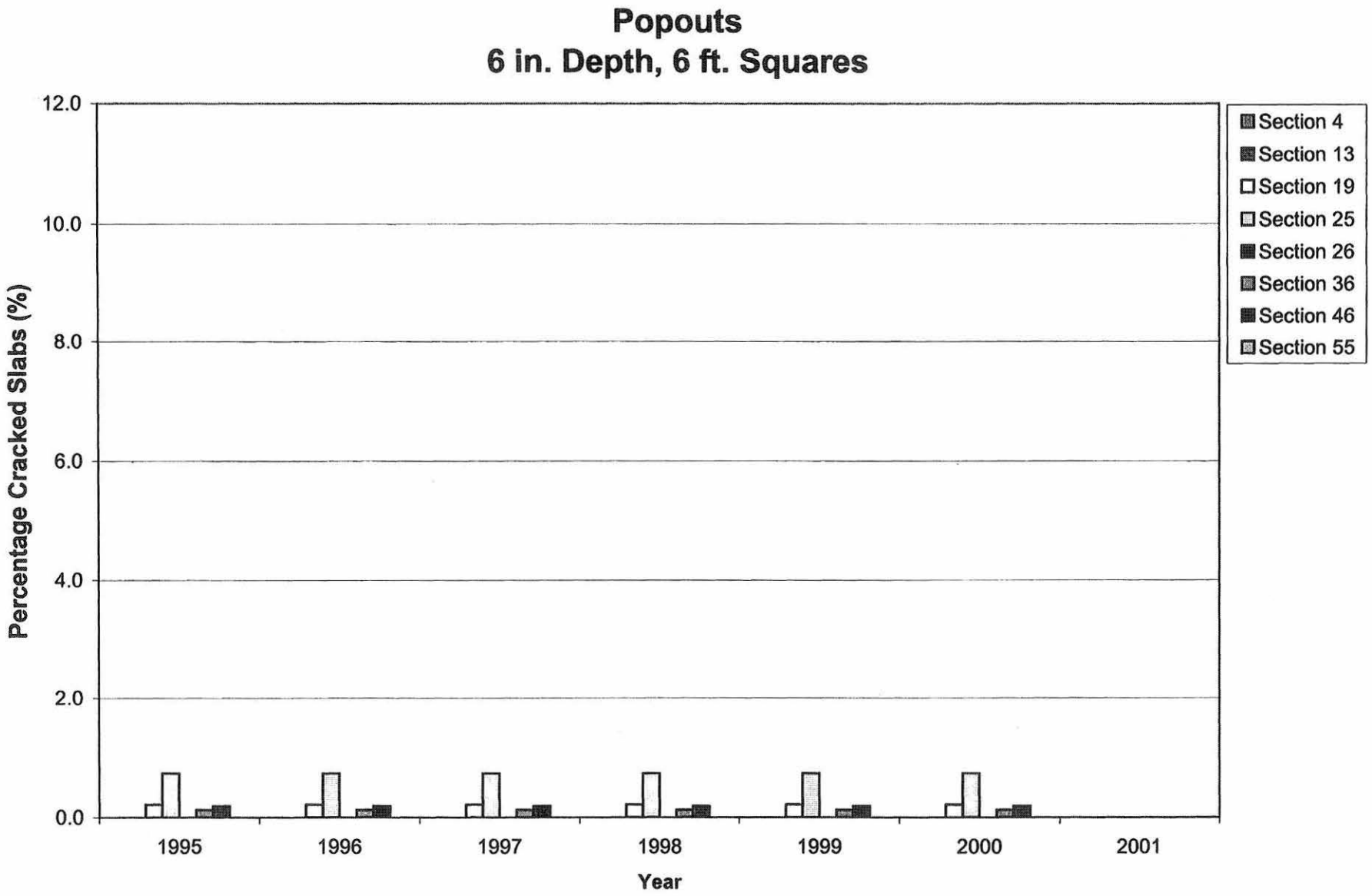

Longitudinal Cracks
4 in. Depth, 6 ft. Squares
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Percentage Cracked Slabs (%)
1995
1996
1997
1998
1999
2000
2001
Year
Section 6
Section 43
Section 48
Section 58

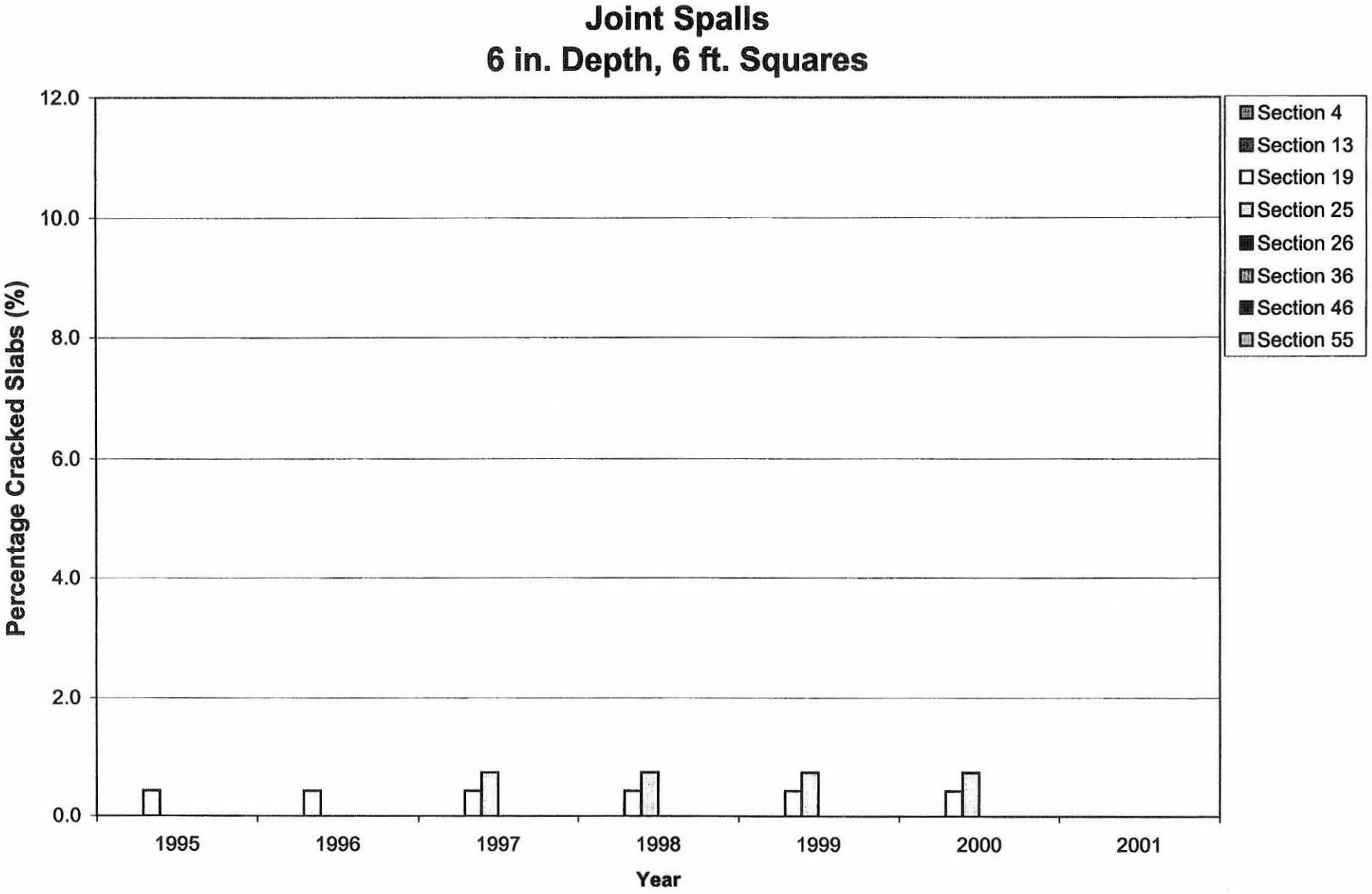

Joint Spalls
4 in. Depth, 6 ft. Squares
Percentage Cracked Slabs (%)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1995
1996
1997
1998
1999
2000
2001
Year
Section 6
Section 43
Section 48
Section 58

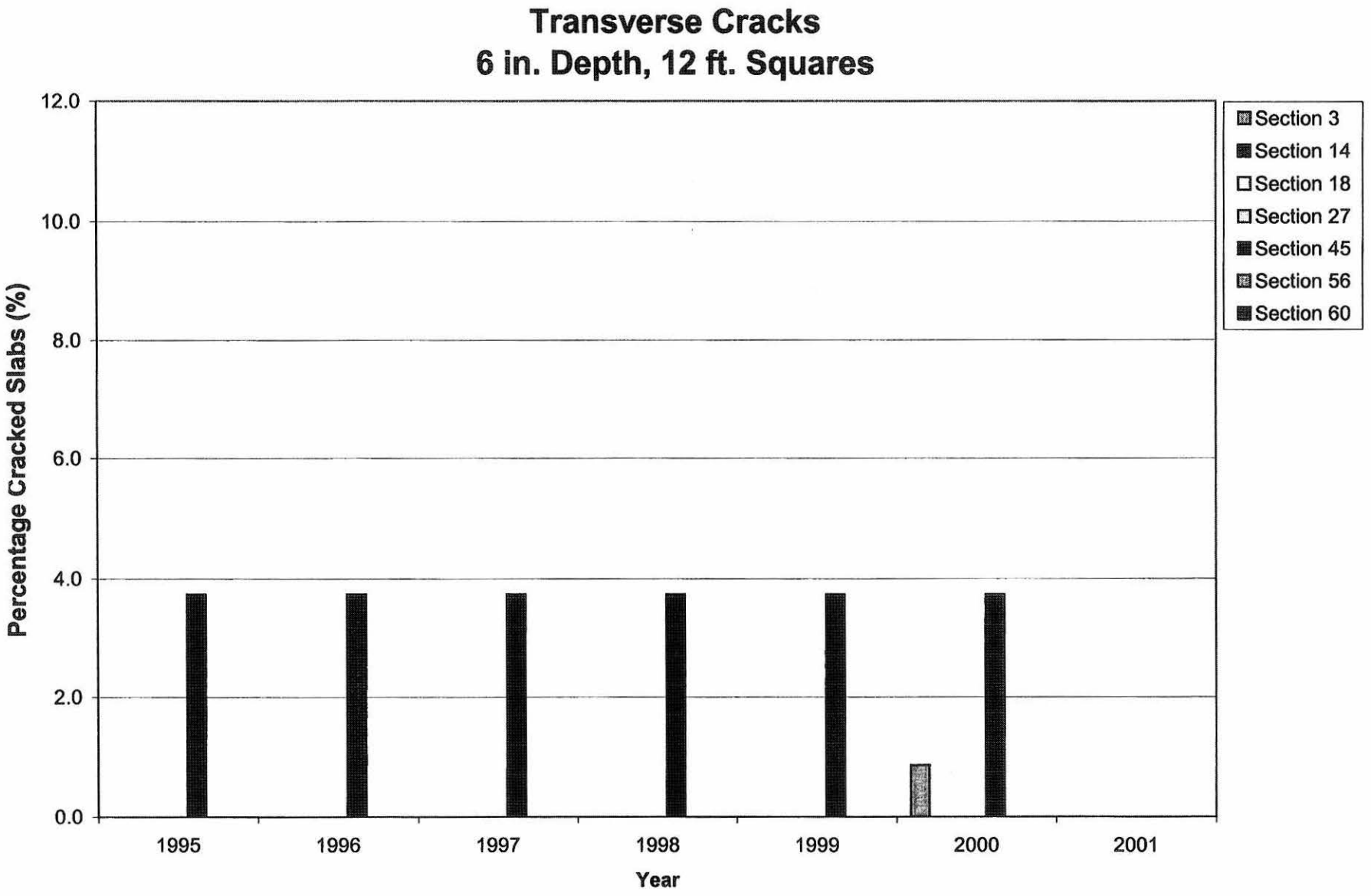

Transverse Cracks
6 in. Depth, 6 ft. Squares
Percentage Cracked Slabs (%)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1995
1996
1997
1998
1999
2000
2001
Year
Section 4
Section 13
Section 19
Section 25
Section 26
Section 36
Section 46
Section 55

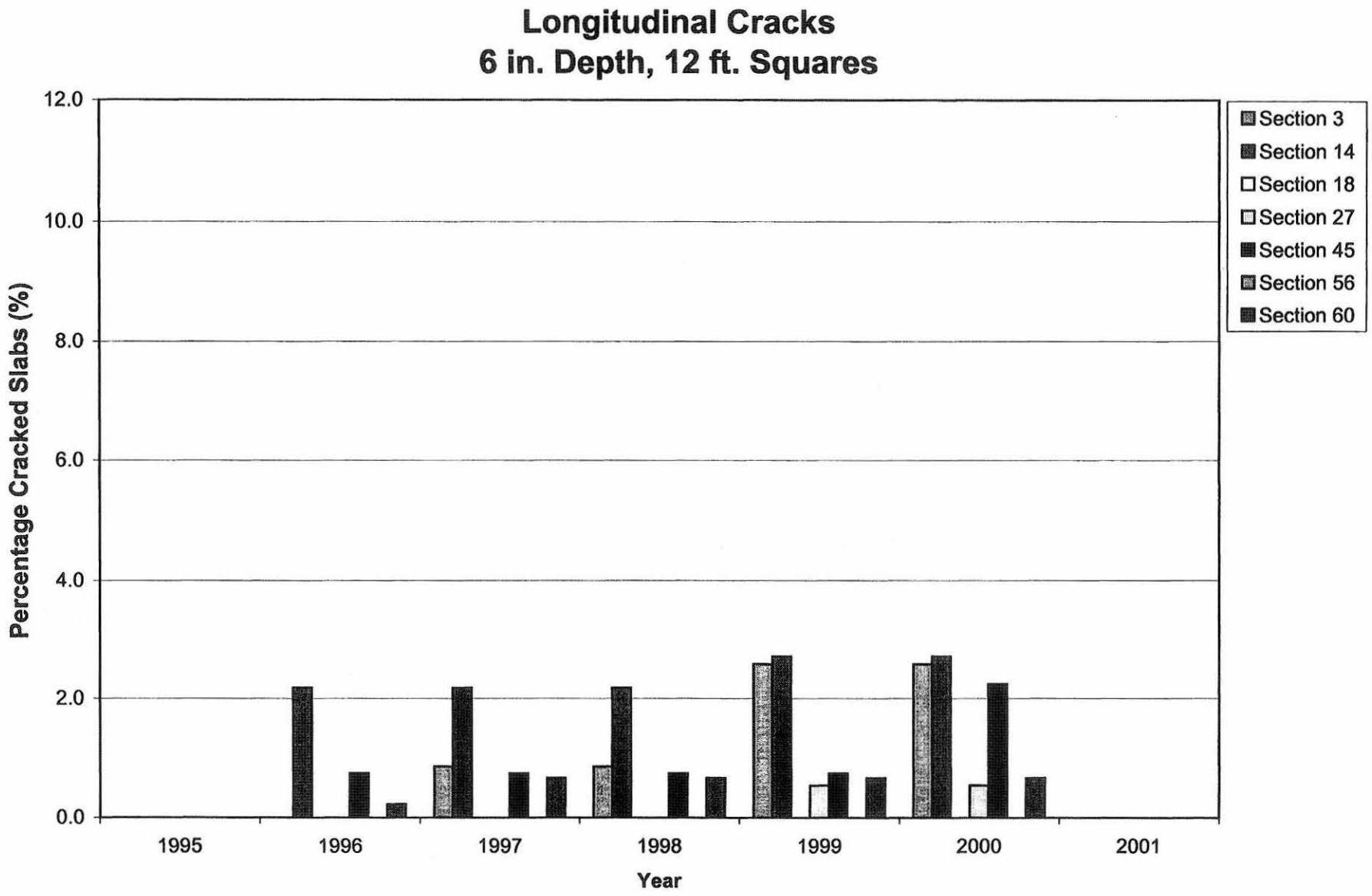

Longitudinal Cracks
6 in. Depth, 6 ft. Squares
Percentage Cracked Slabs (%)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1995
1996
1997
1998
1999
2000
2001
Year
Section 4
Section 13
Section 19
Section 25
Section 26
Section 36
Section 46
Section 55

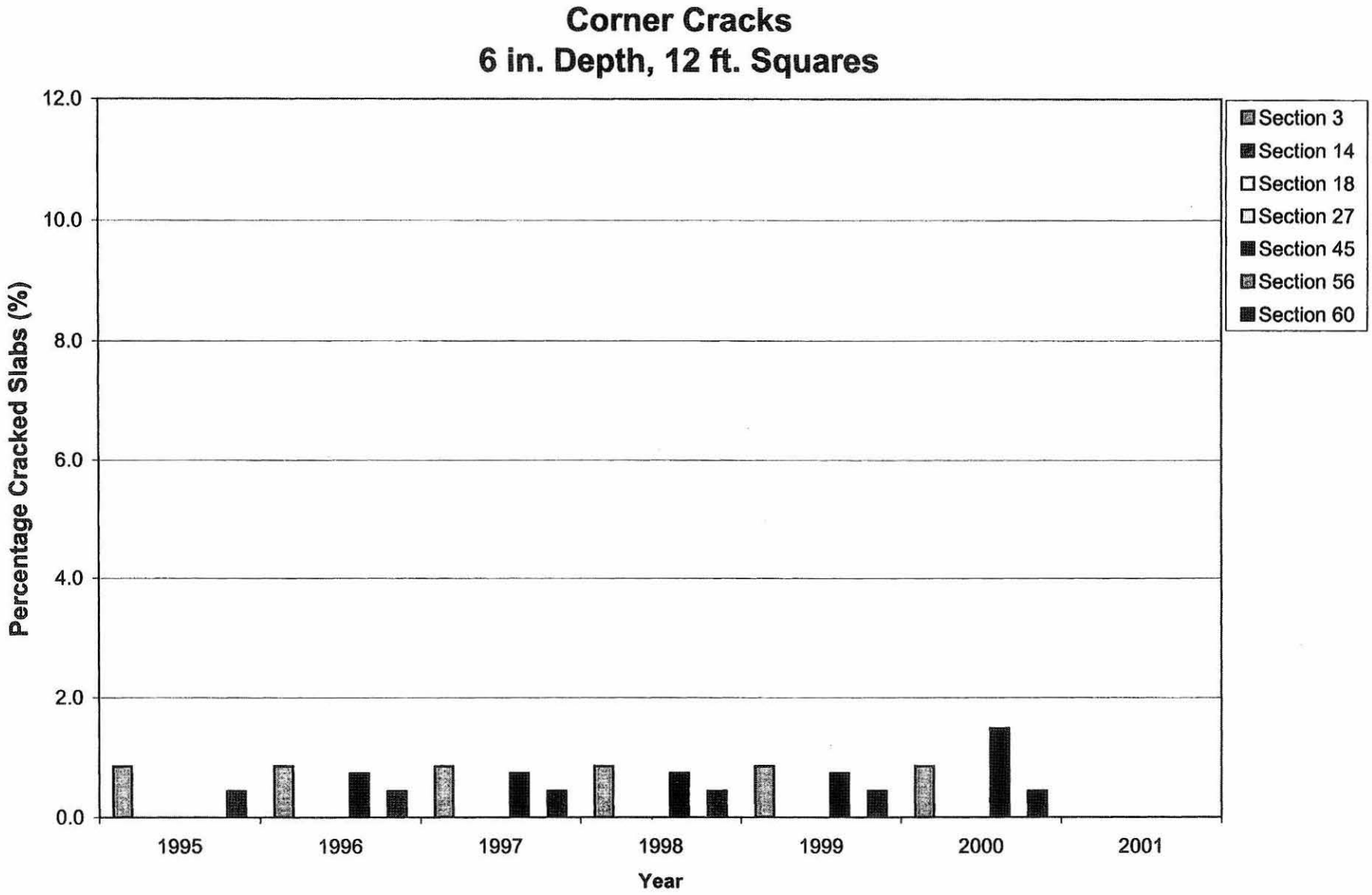

Corner Cracks
6 in. Depth, 6 ft. Squares
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Percentage Cracked Slabs (%)
1995
1996
1997
1998
1999
2000
2001
Year
Section 4
Section 13
Section 19
Section 25
Section 26
Section 36
Section 46
Section 55

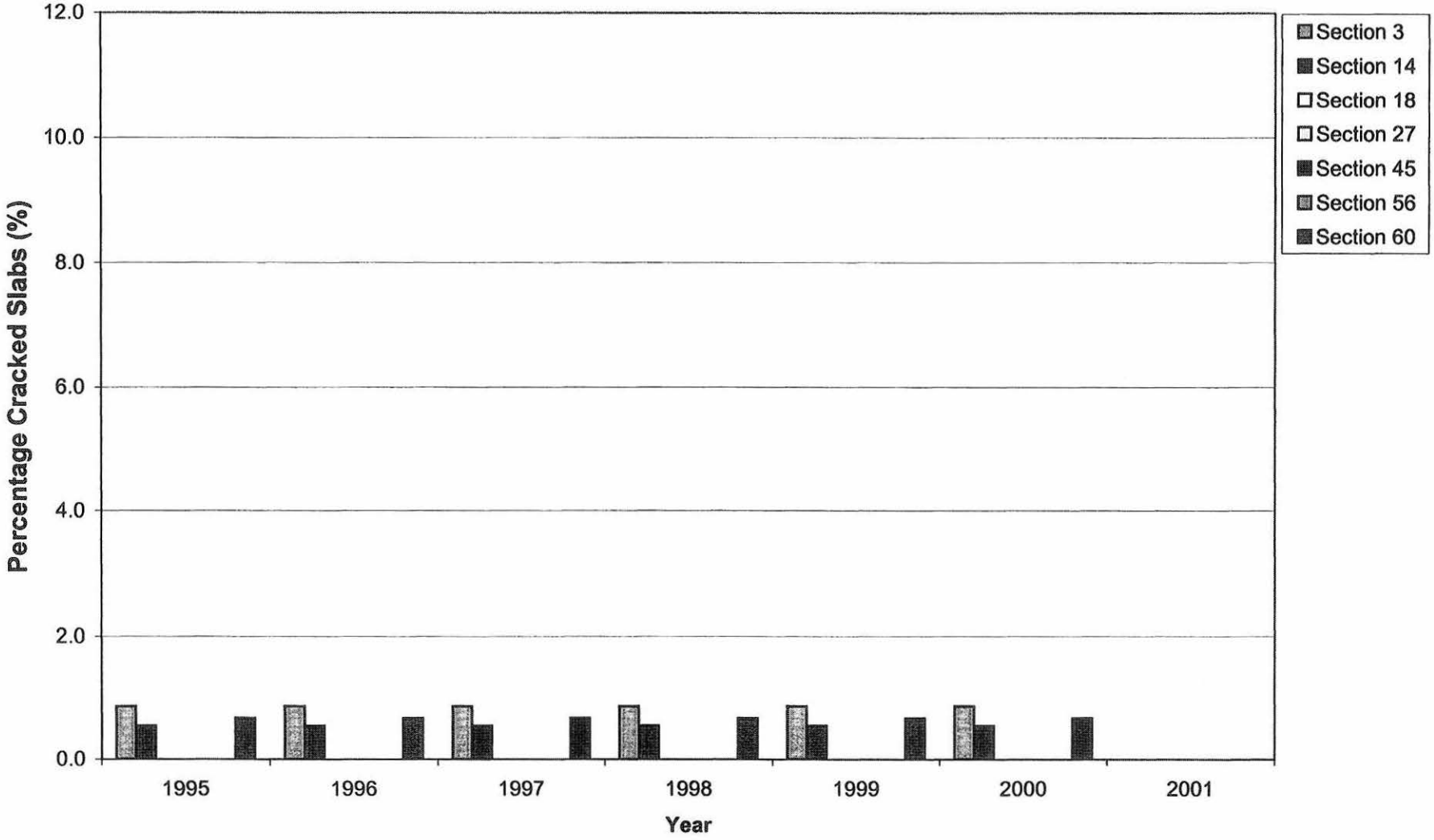

Popouts
6 in. Depth, 6 ft. Squares
Percentage Cracked Slabs (%)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1995
1996
1997
1998
1999
2000
2001
Year
Section 4
Section 13
Section 19
Section 25
Section 26
Section 36
Section 46
Section 55

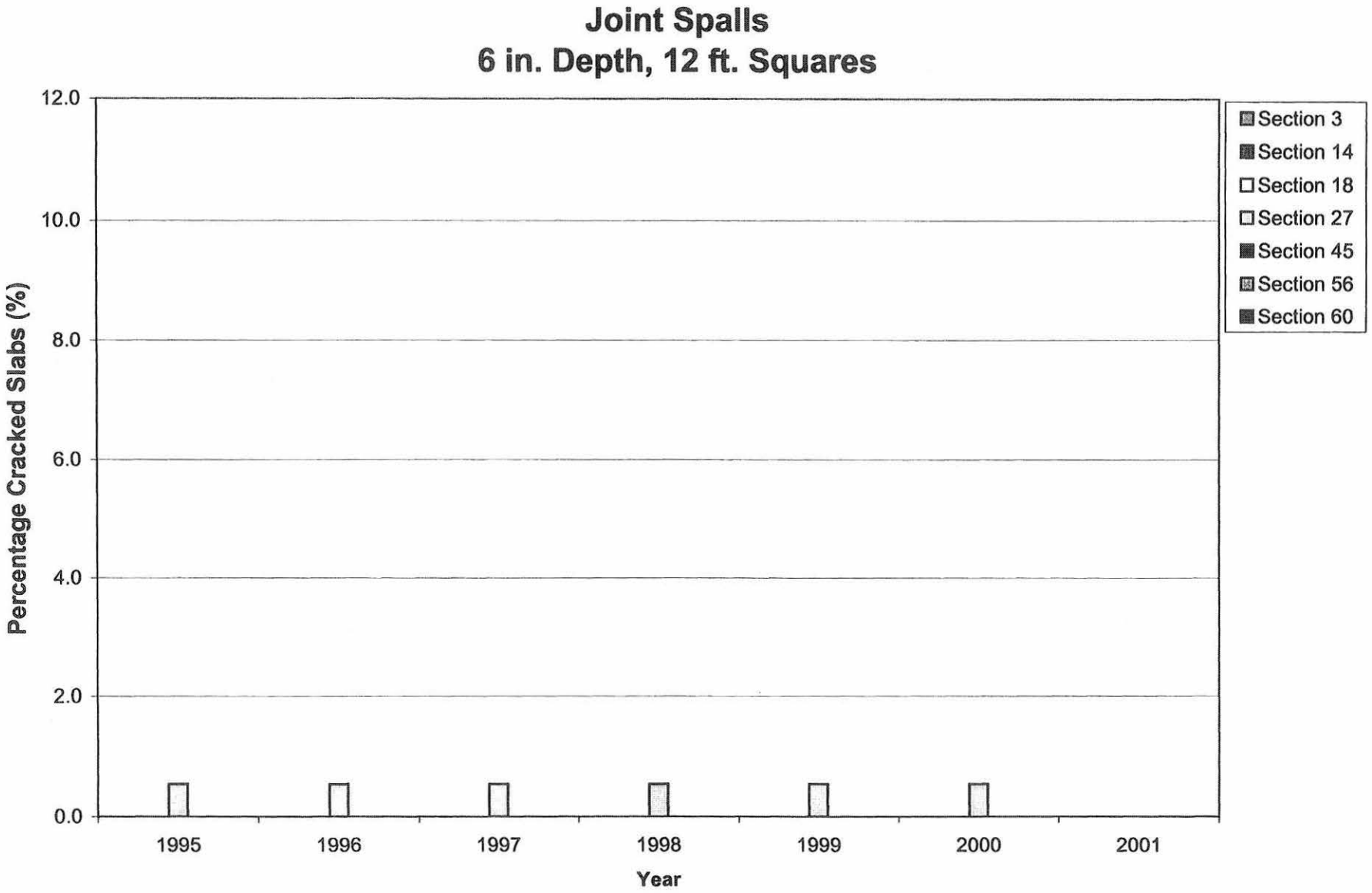

Joint Spalls
6 in. Depth, 6 ft. Squares
Percentage Cracked Slabs (%)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1995
1996
1997
1998
1999
2000
2001
Year
Section 4
Section 13
Section 19
Section 25
Section 26
Section 36
Section 46
Section 55

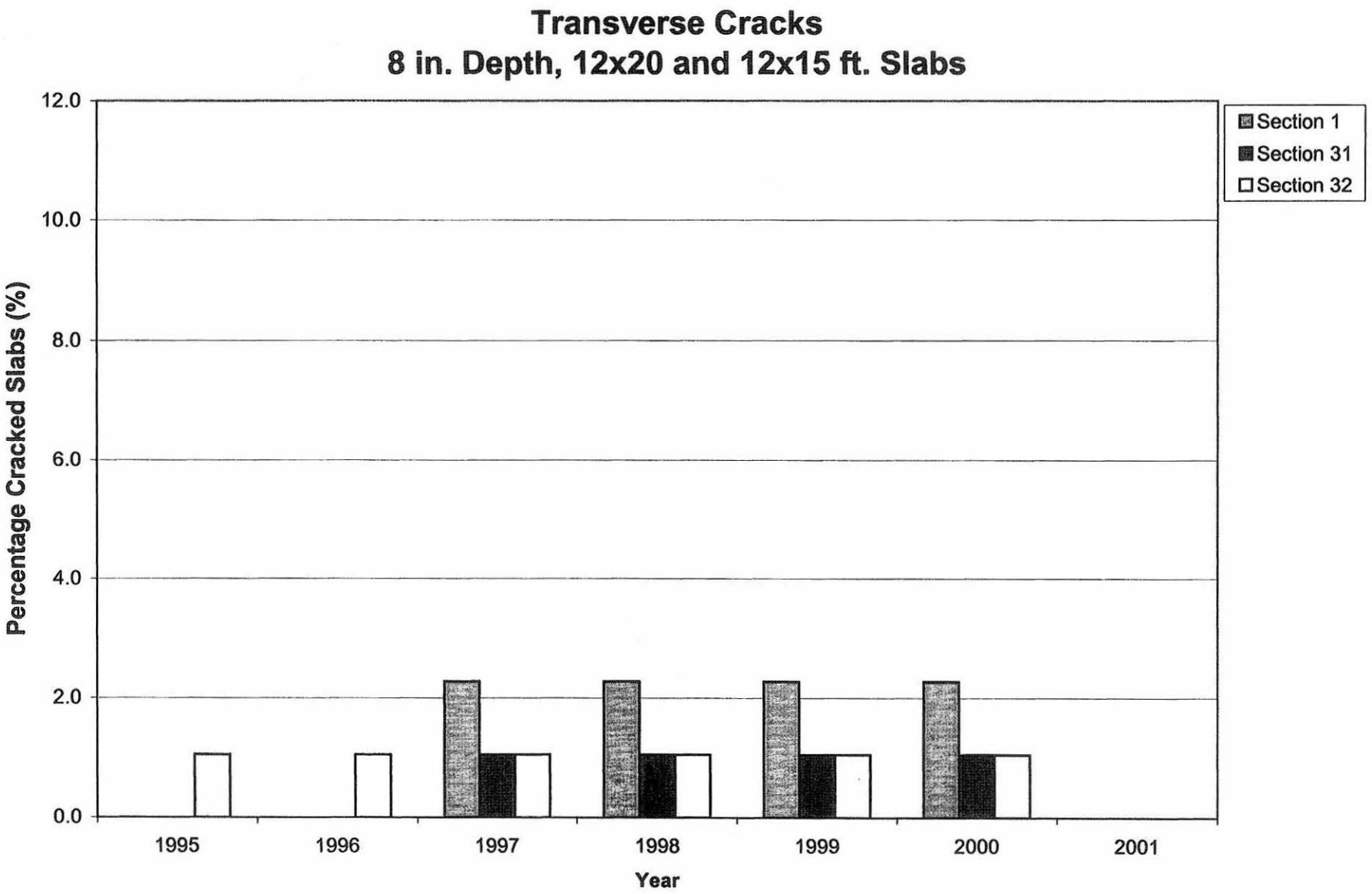

Transverse Cracks
6 in. Depth, 12 ft. Squares
Percentage Cracked Slabs (%)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1995
1996
1997
1998
1999
2000
2001
Year
Section 3
Section 14
Section 18
Section 27
Section 45
Section 56
Section 60

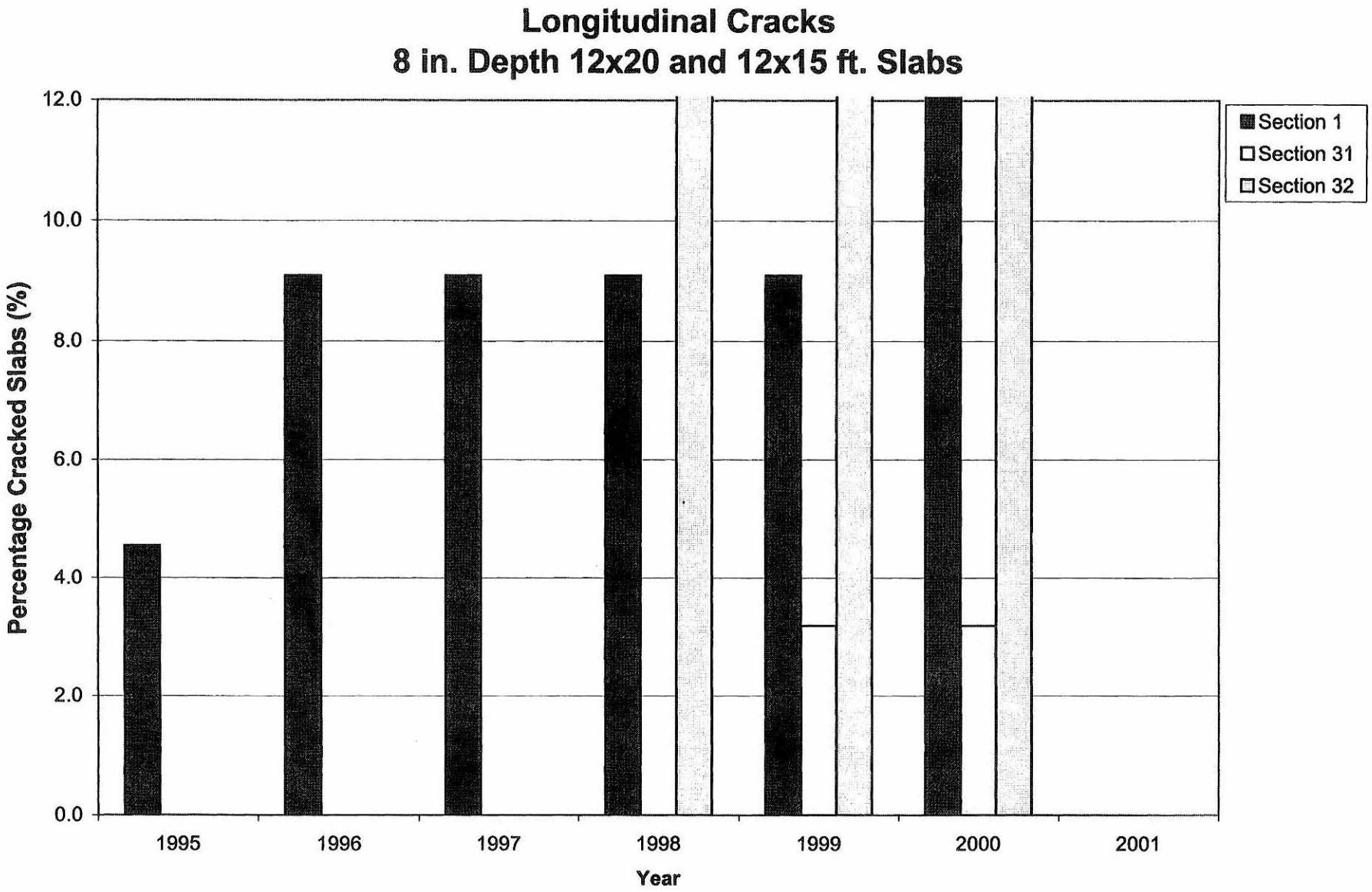

Longitudinal Cracks
6 in. Depth, 12 ft. Squares
Percentage Cracked Slabs (%)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1995
1996
1997
1998
1999
2000
2001
Year
Section 3
Section 14
Section 18
Section 27
Section 45
Section 56
Section 60

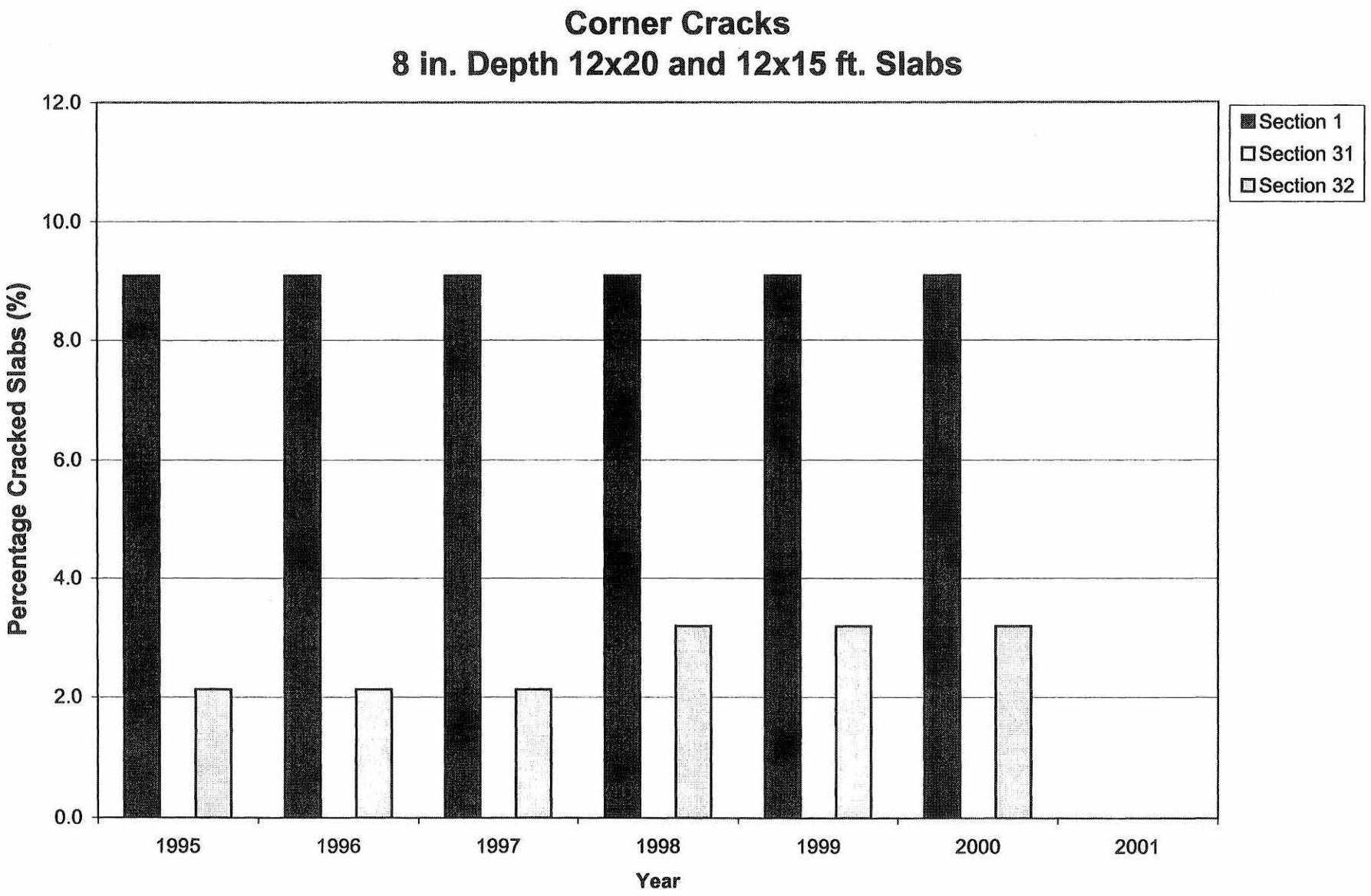

Corner Cracks
6 in. Depth, 12 ft. Squares
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Percentage Cracked Slabs (%)
1995
1996
1997
1998
1999
2000
2001
Year
Section 3
Section 14
Section 18
Section 27
Section 45
Section 56
Section 60

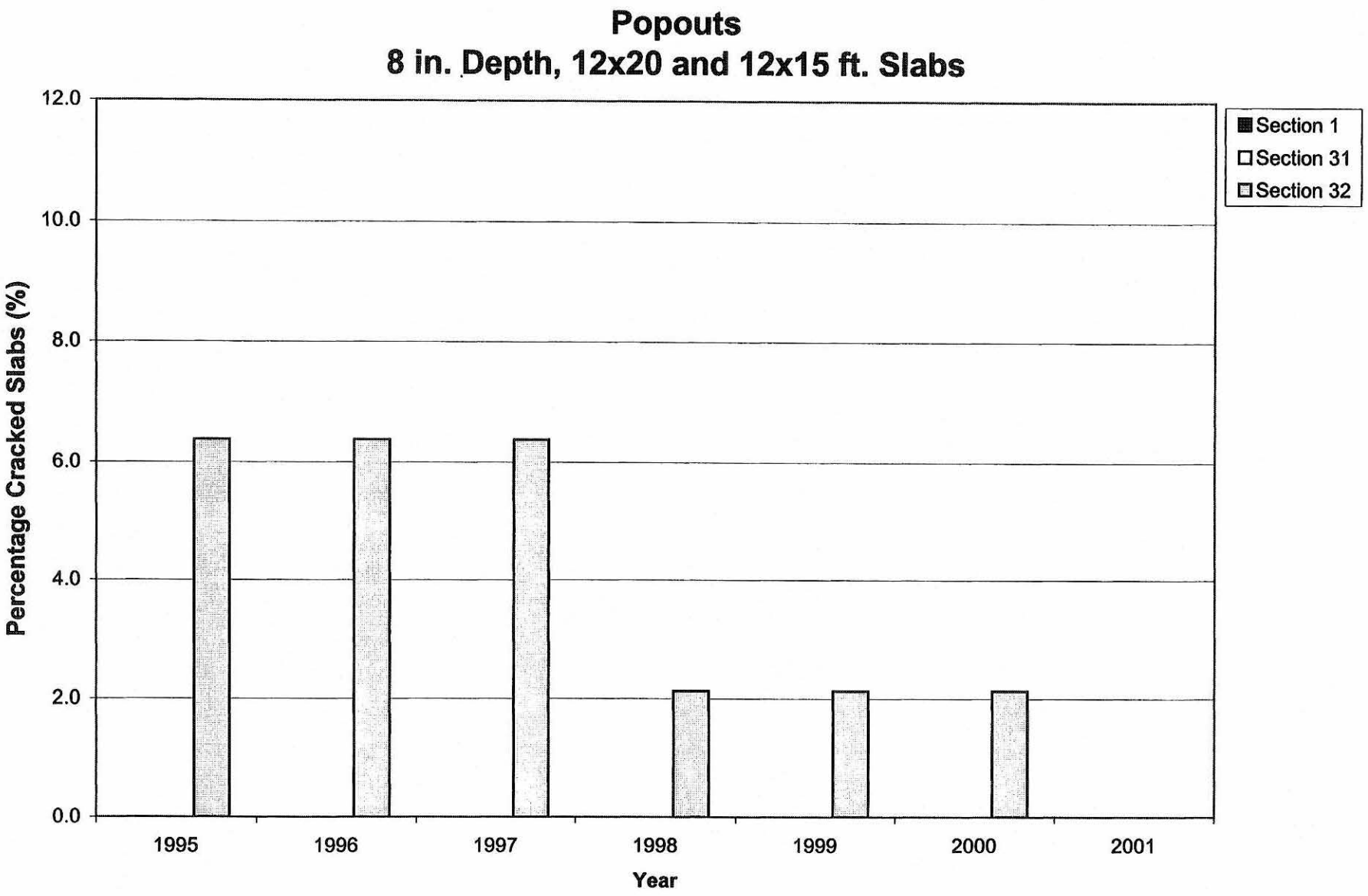

Popouts
6 in. Depth, 12 ft. Squares
Percentage Cracked Slabs (%)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1995
1996
1997
1998
1999
2000
2001
Year
Section 3
Section 14
Section 18
Section 27
Section 45
Section 56
Section 60

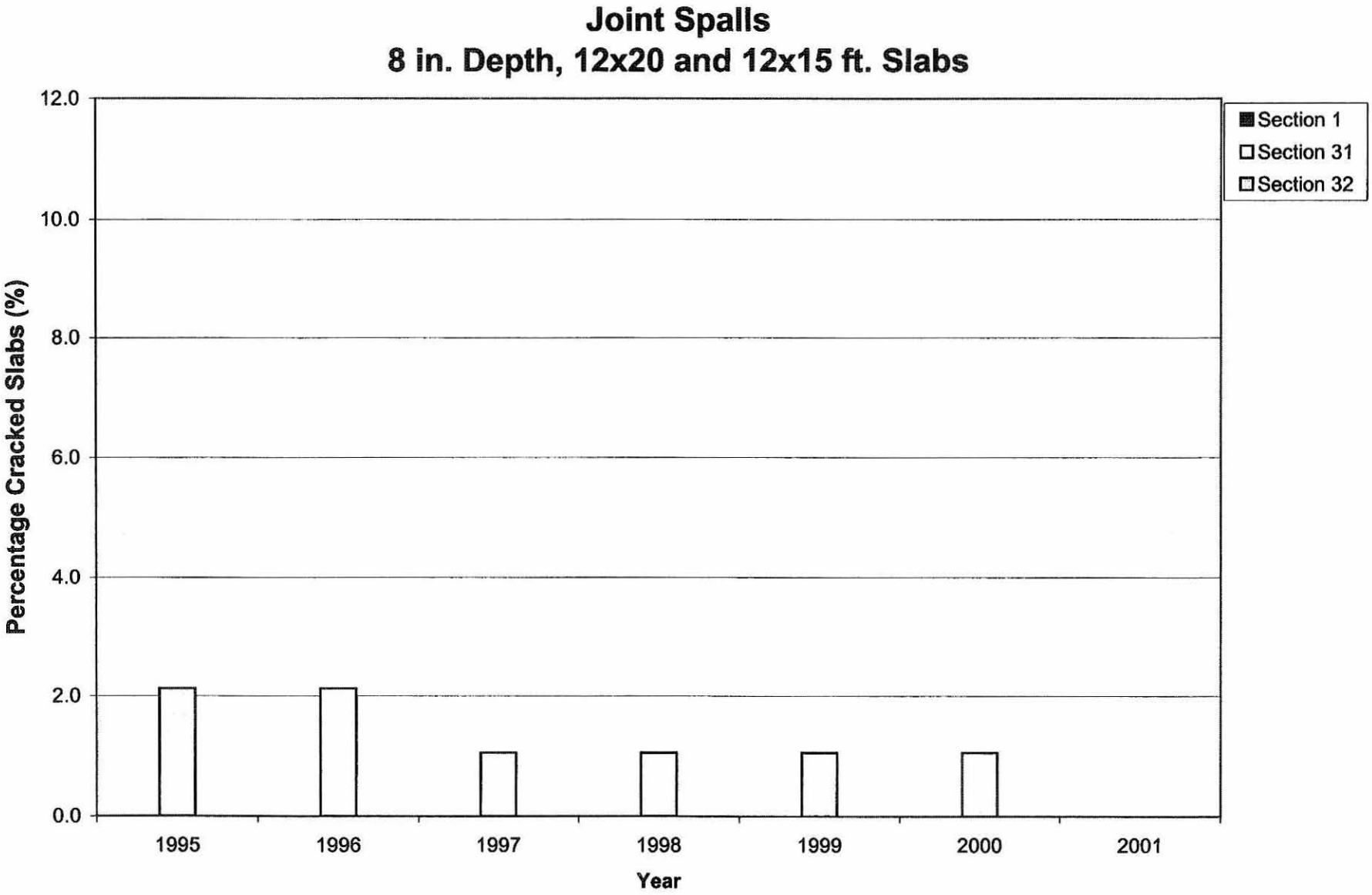

Joint Spalls
6 in. Depth, 12 ft. Squares
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Percentage Cracked Slabs (%)
1995
1996
1997
1998
1999
2000
2001
Year
Section 3
Section 14
Section 18
Section 27
Section 45
Section 56
Section 60

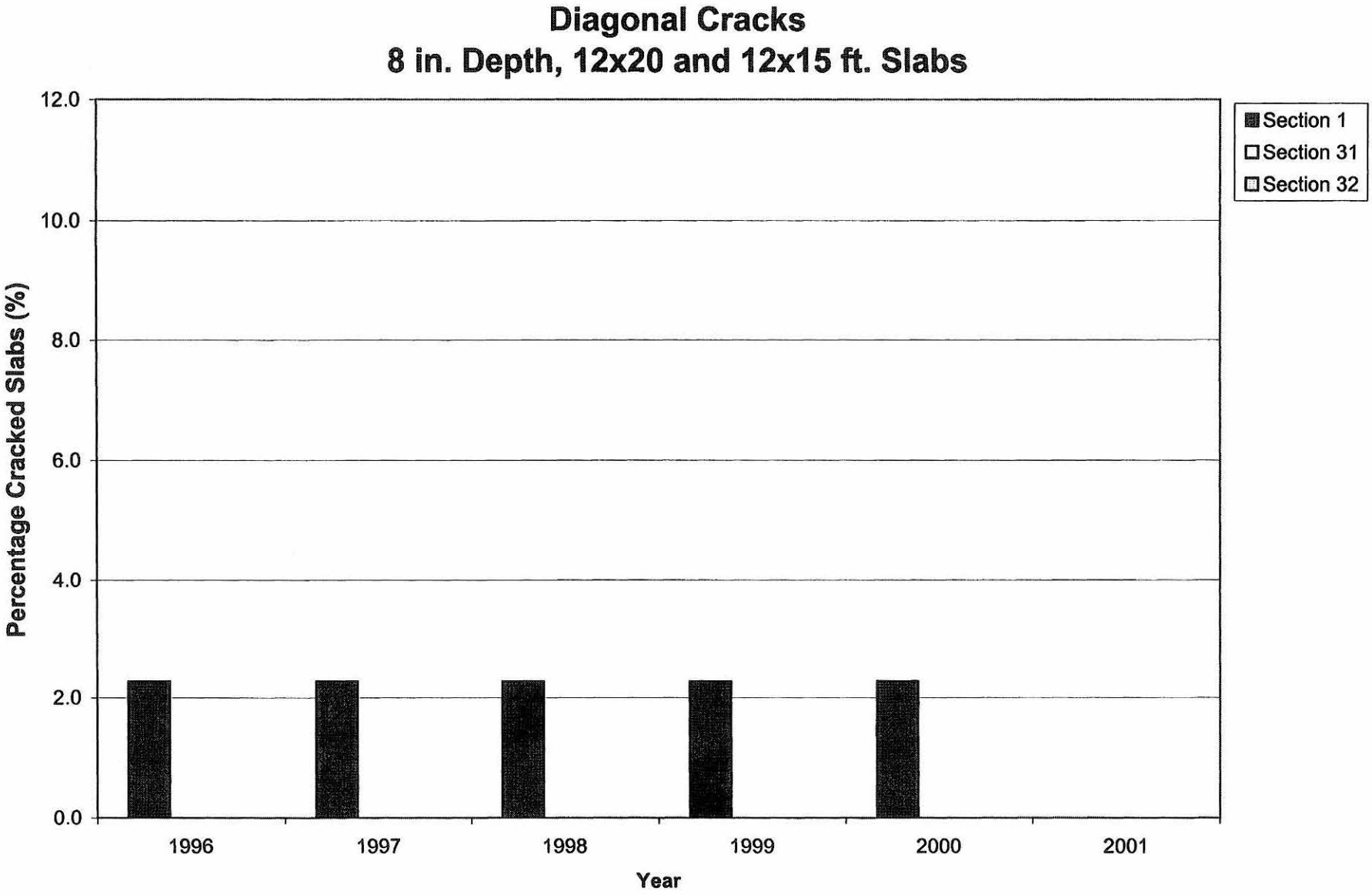

Transverse Cracks
8 in. Depth, 12x20 and 12x15 ft. Slabs
Percentage Cracked Slabs (%)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1995
1996
1997
1998
1999
2000
2001
Year
Section 1
Section 31
Section 32

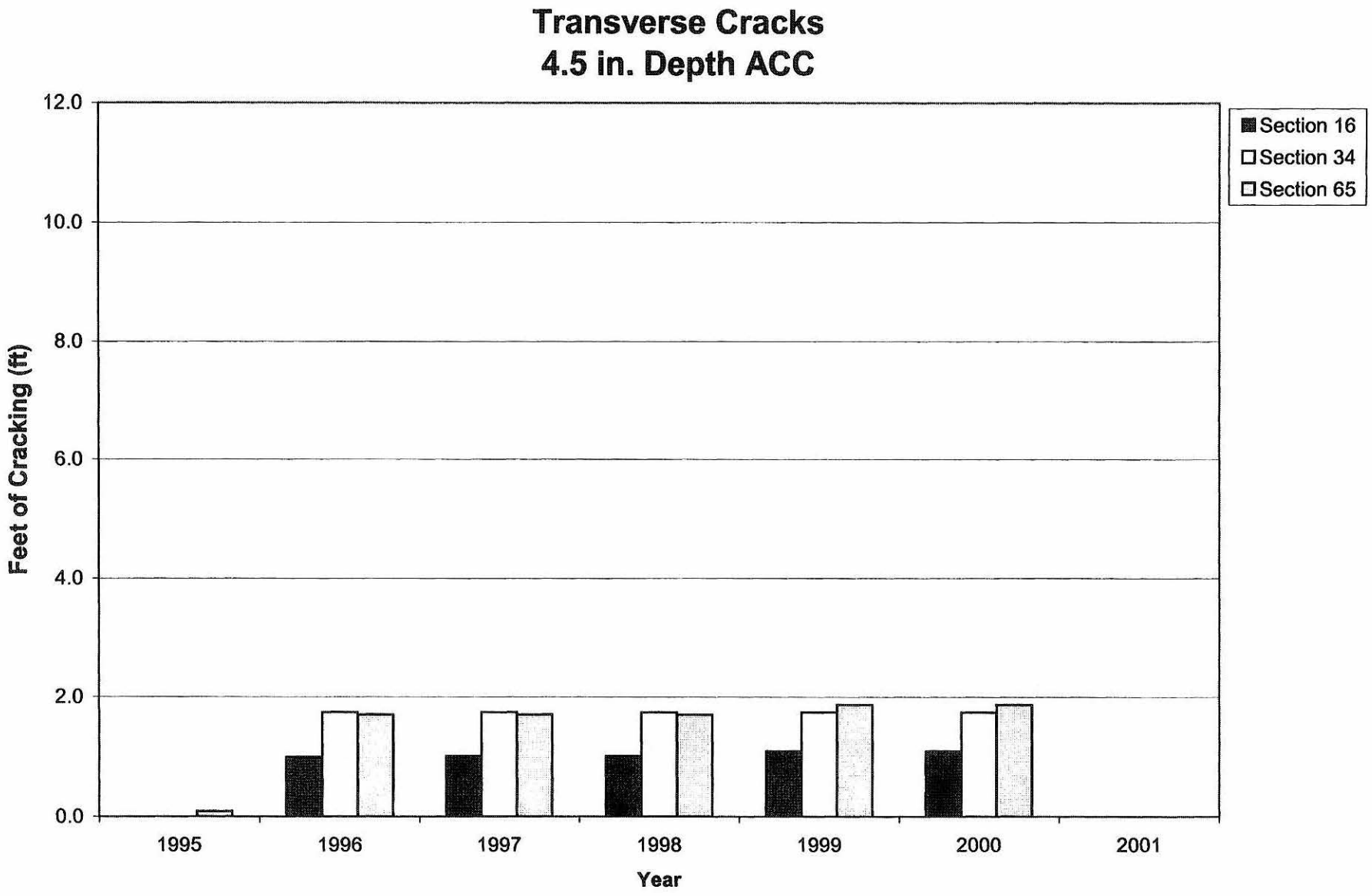

Longitudinal Cracks
8 in. Depth 12x20 and 12x15 ft. Slabs
Percentage Cracked Slabs (%)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1995
1996
1997
1998
1999
2000
2001
Year
Section 1
Section 31
Section 32

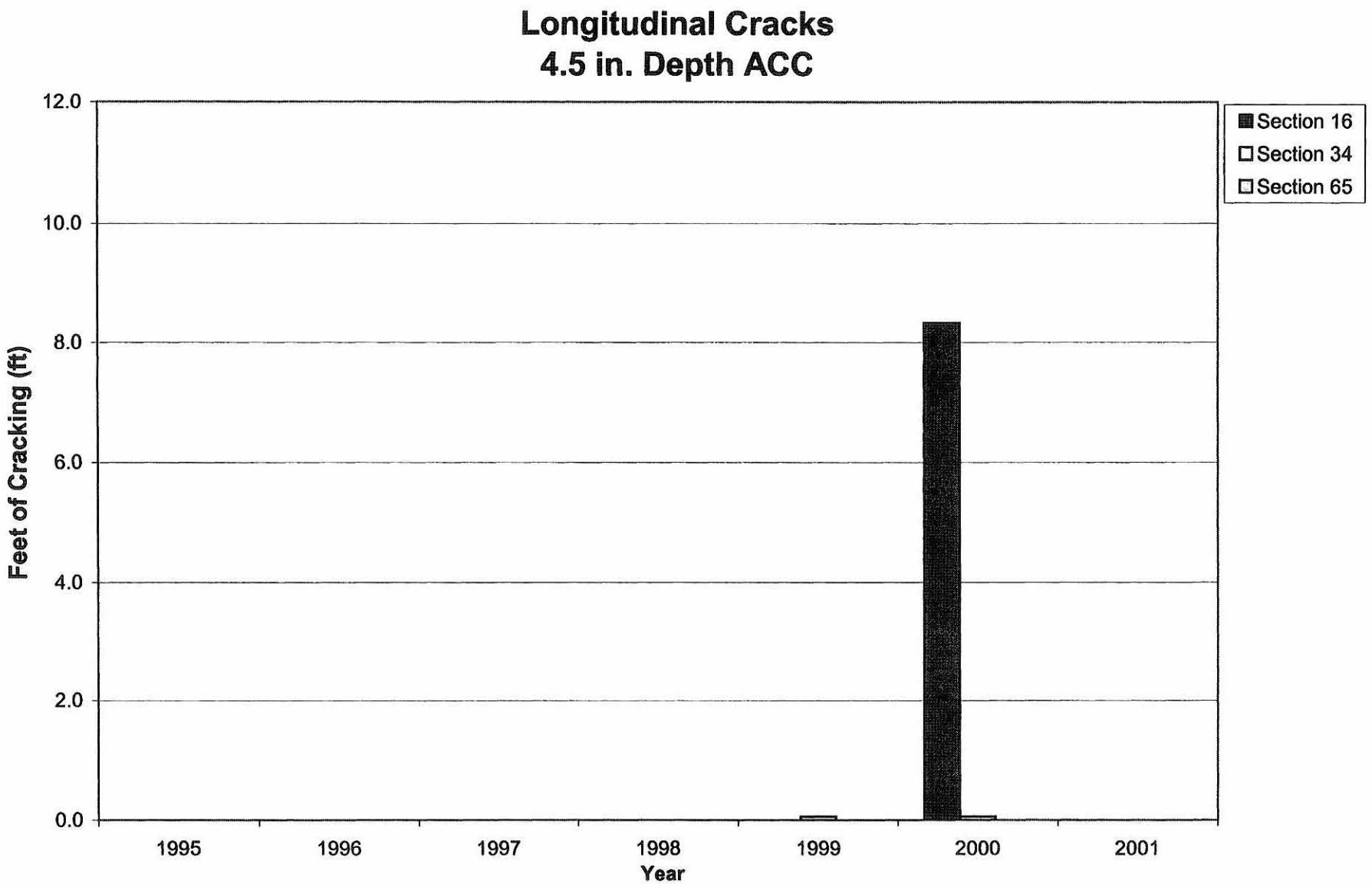

Corner Cracks
8 in. Depth 12x20 and 12x15 ft. Slabs
Percentage Cracked Slabs (%)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1995
1996
1997
1998
1999
2000
2001
Year
Section 1
Section 31
Section 32

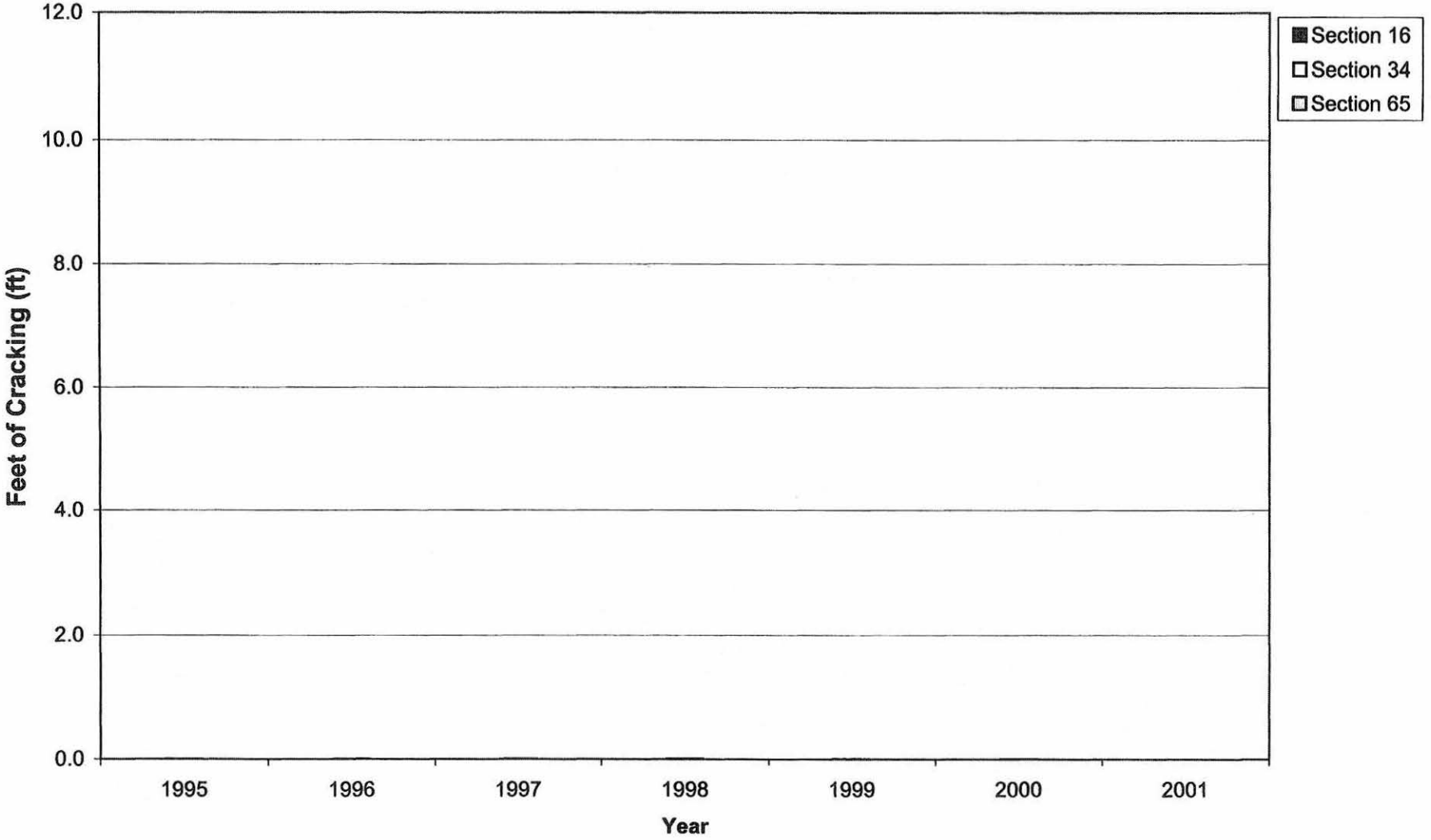

Popouts
8 in. Depth, 12x20 and 12x15 ft. Slabs
Percentage Cracked Slabs (%)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1995
1996
1997
1998
1999
2000
2001
Year
Section 1
Section 31
Section 32

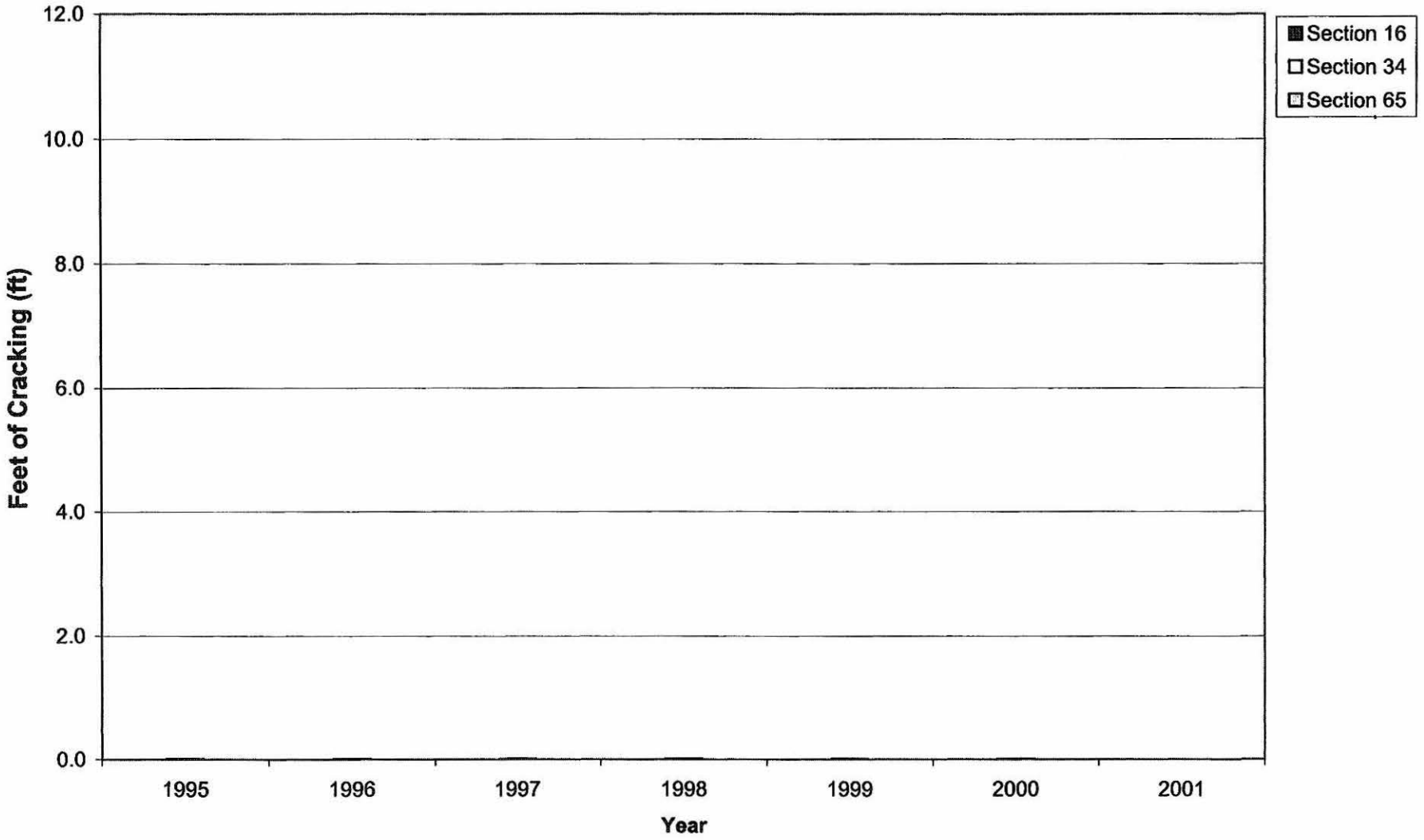

Joint Spalls
8 in. Depth, 12x20 and 12x15 ft. Slabs
Percentage Cracked Slabs (%)
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1995
1996
1997
1998
1999
2000
2001
Year
Section 1
Section 31
Section 32

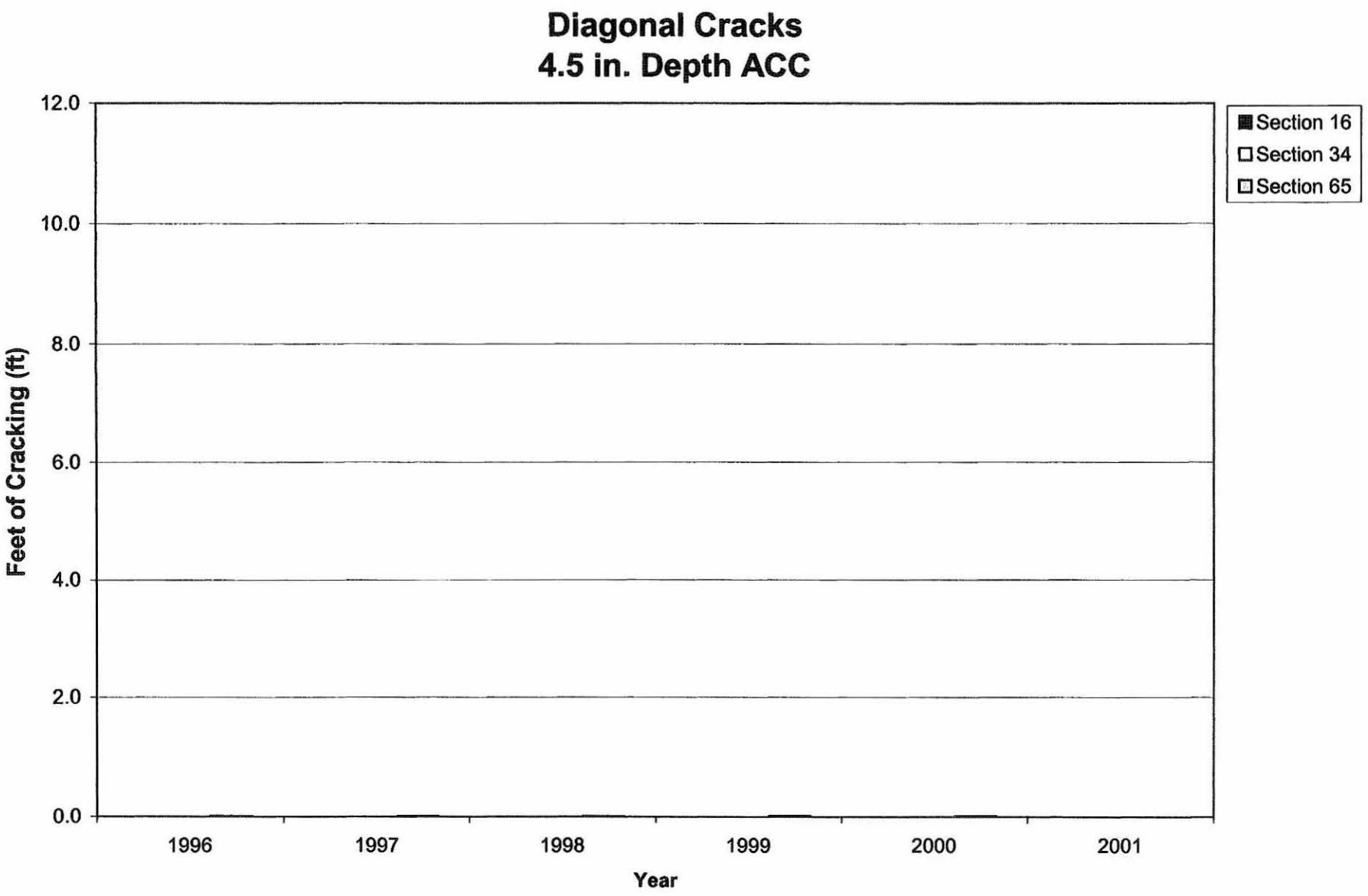

Diagonal Cracks
8 in. Depth, 12x20 and 12x15 ft. Slabs
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Percentage Cracked Slabs (%)
1996
1997
1998
1999
2000
2001
Year
Section 1
Section 31
Section 32


Transverse Cracks
4.5 in. Depth ACC
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Feet of Cracking (ft)
1995
1996
1997
1998
1999
2000
2001
Year
Section 16
Section 34
Section 65


Longitudinal Cracks
4.5 in. Depth ACC
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Feet of Cracking (ft)
1995
1996
1997
1998
1999
2000
2001
Year
Section 16
Section 34
Section 65

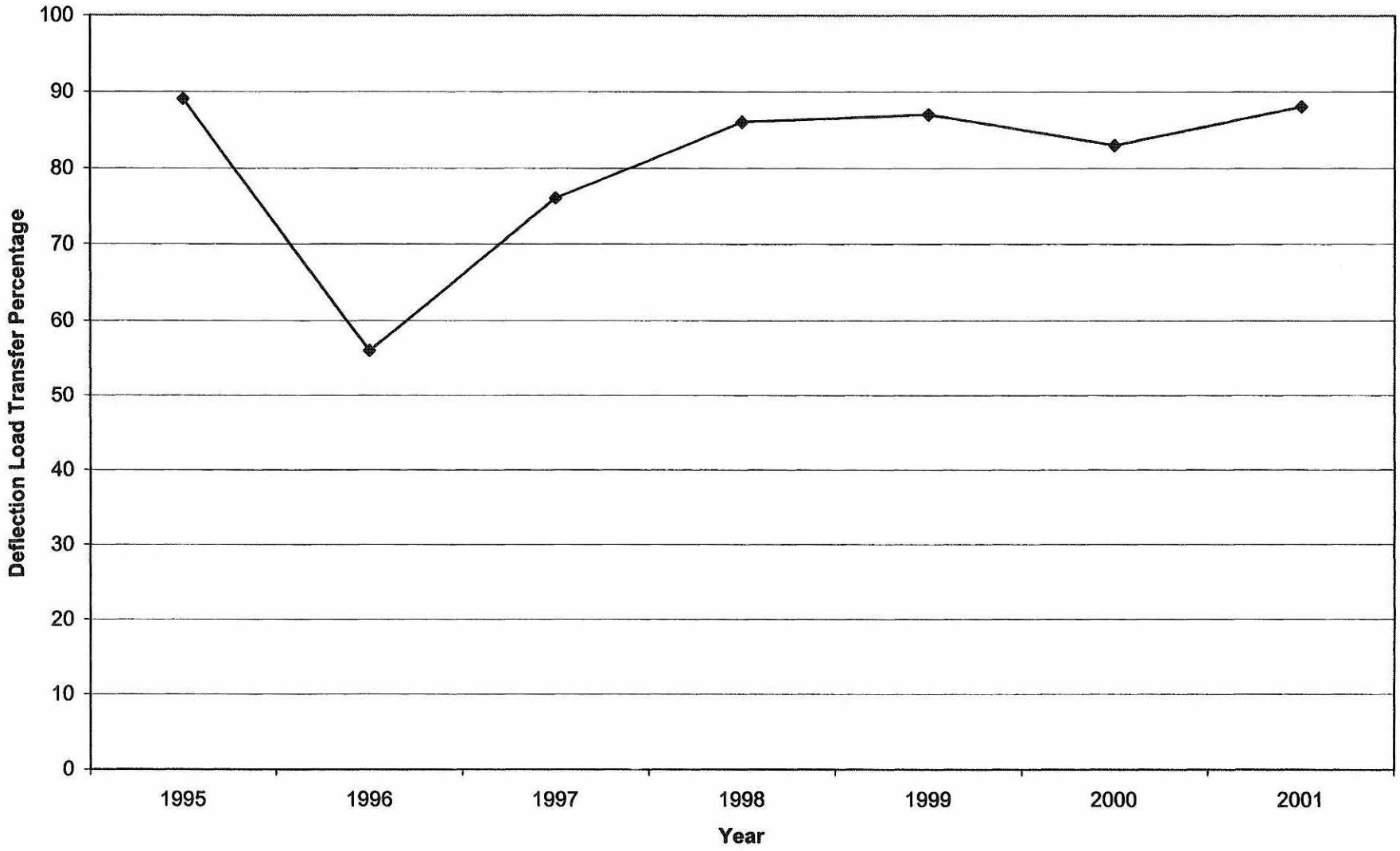

Popouts
4.5 in. Depth ACC
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Feet of Cracking (ft)
1995
1996
1997
1998
1999
2000
2001
Year
Section 16
Section 34
Section 65

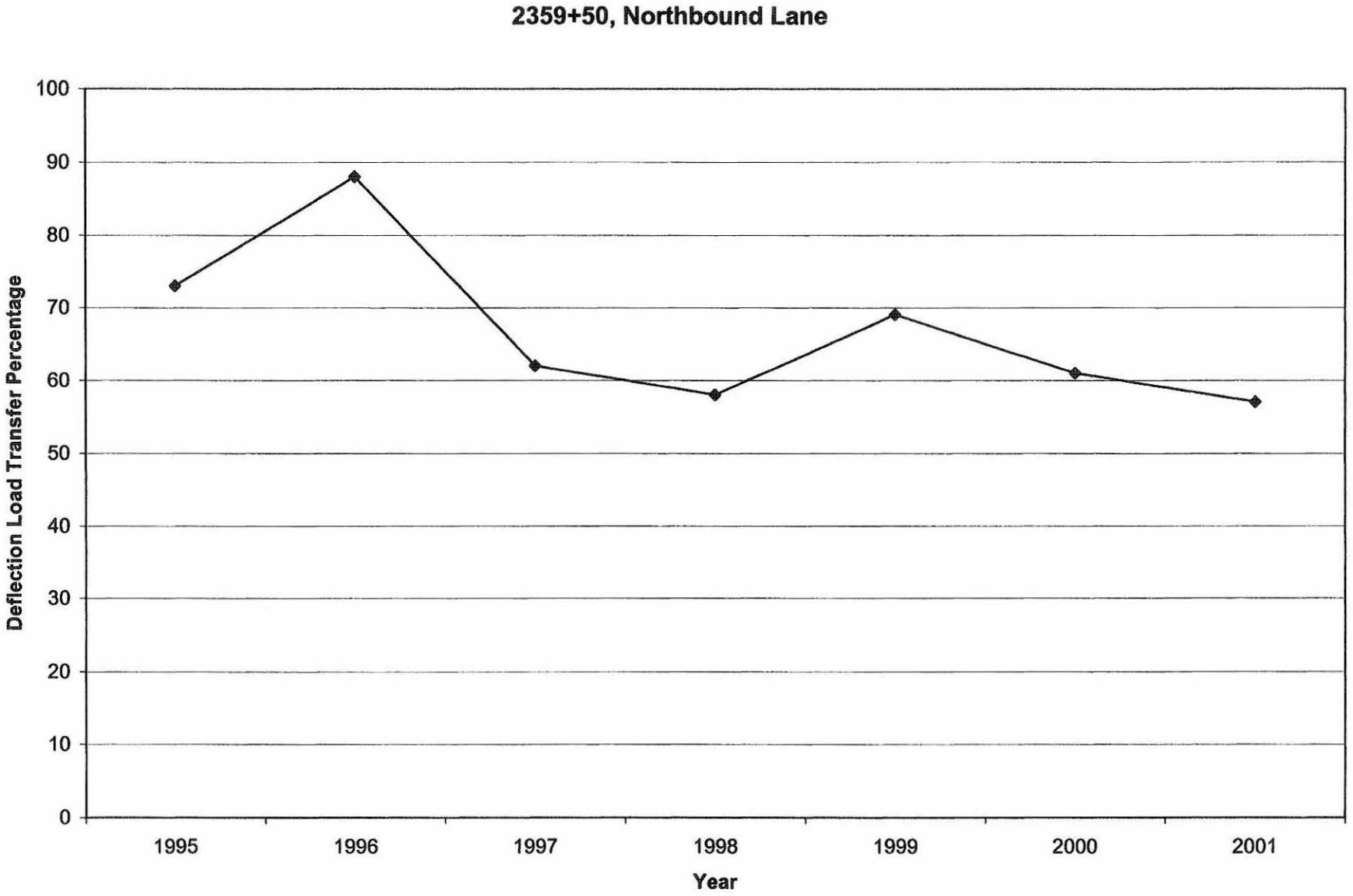

Joint Spalls
4.5 in. Depth ACC
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Feet of Cracking (ft)
1995
1996
1997
1998
1999
2000
2001
Year
Section 16
Section 34
Section 65

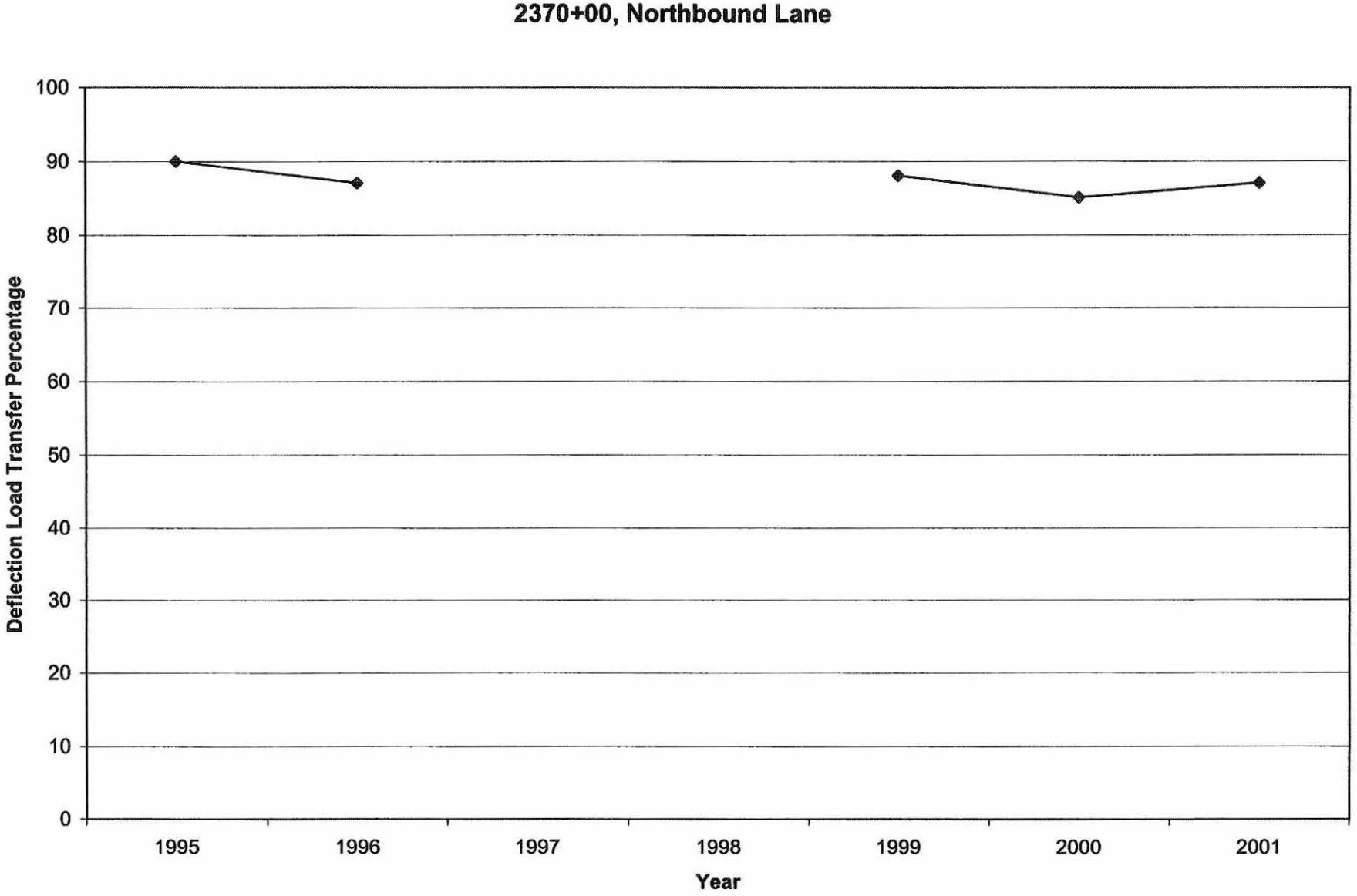

Diagonal Cracks
4.5 in. Depth ACC
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Feet of Cracking (ft)
1996
1997
1998
1999
2000
2001
Year
Section 16
Section 34
Section 65

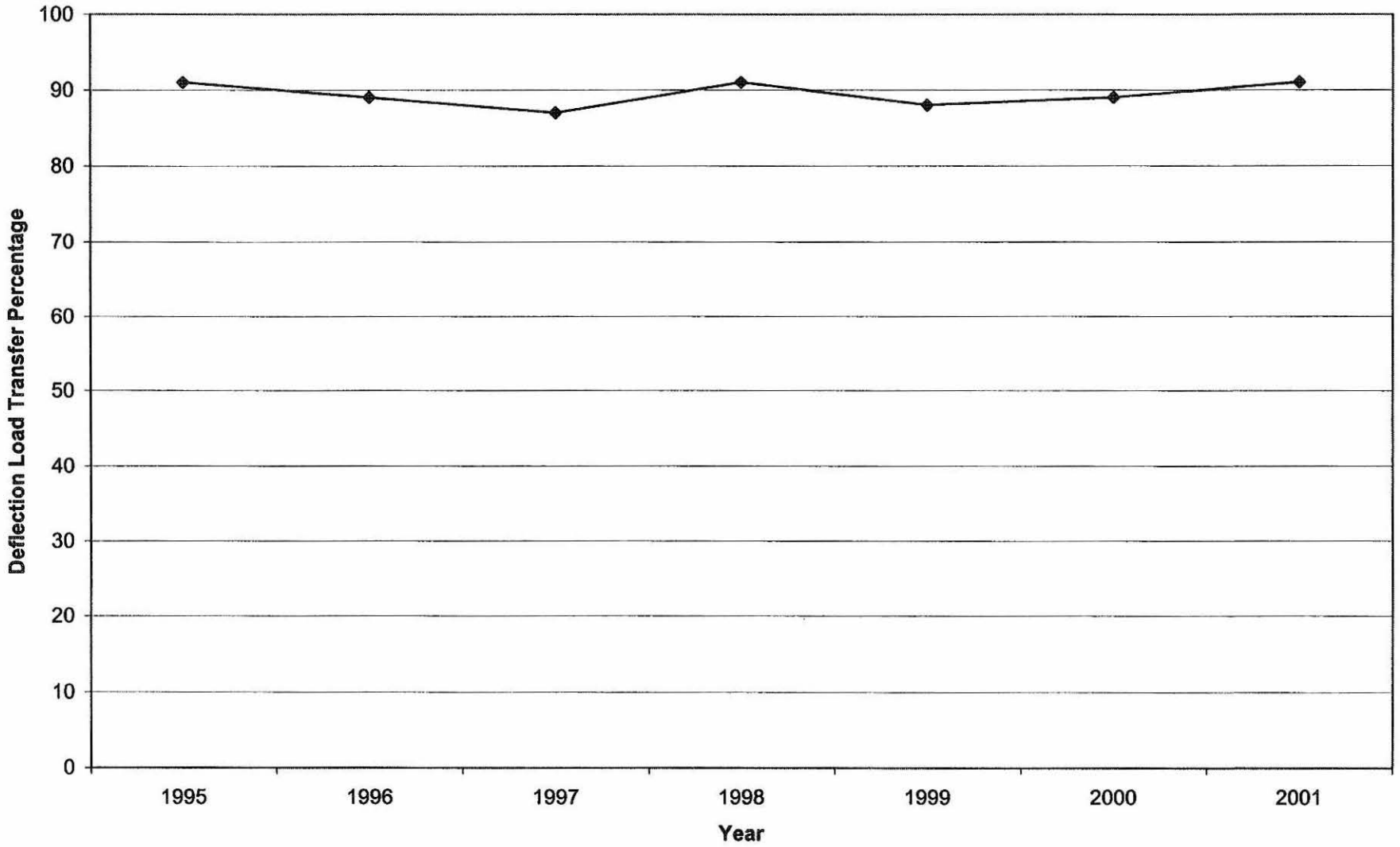
APPENDIX B

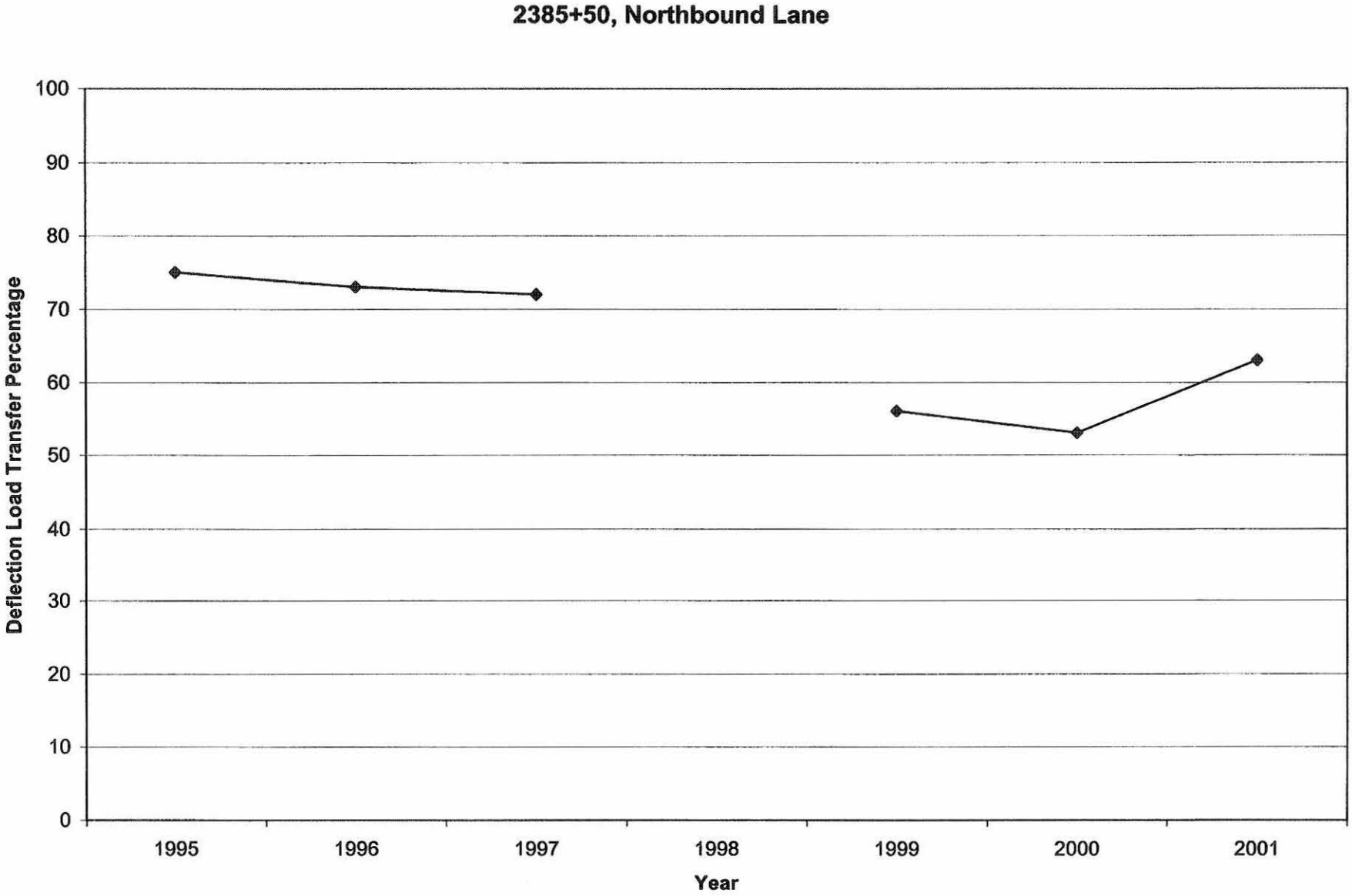
Deflection Load Transfer

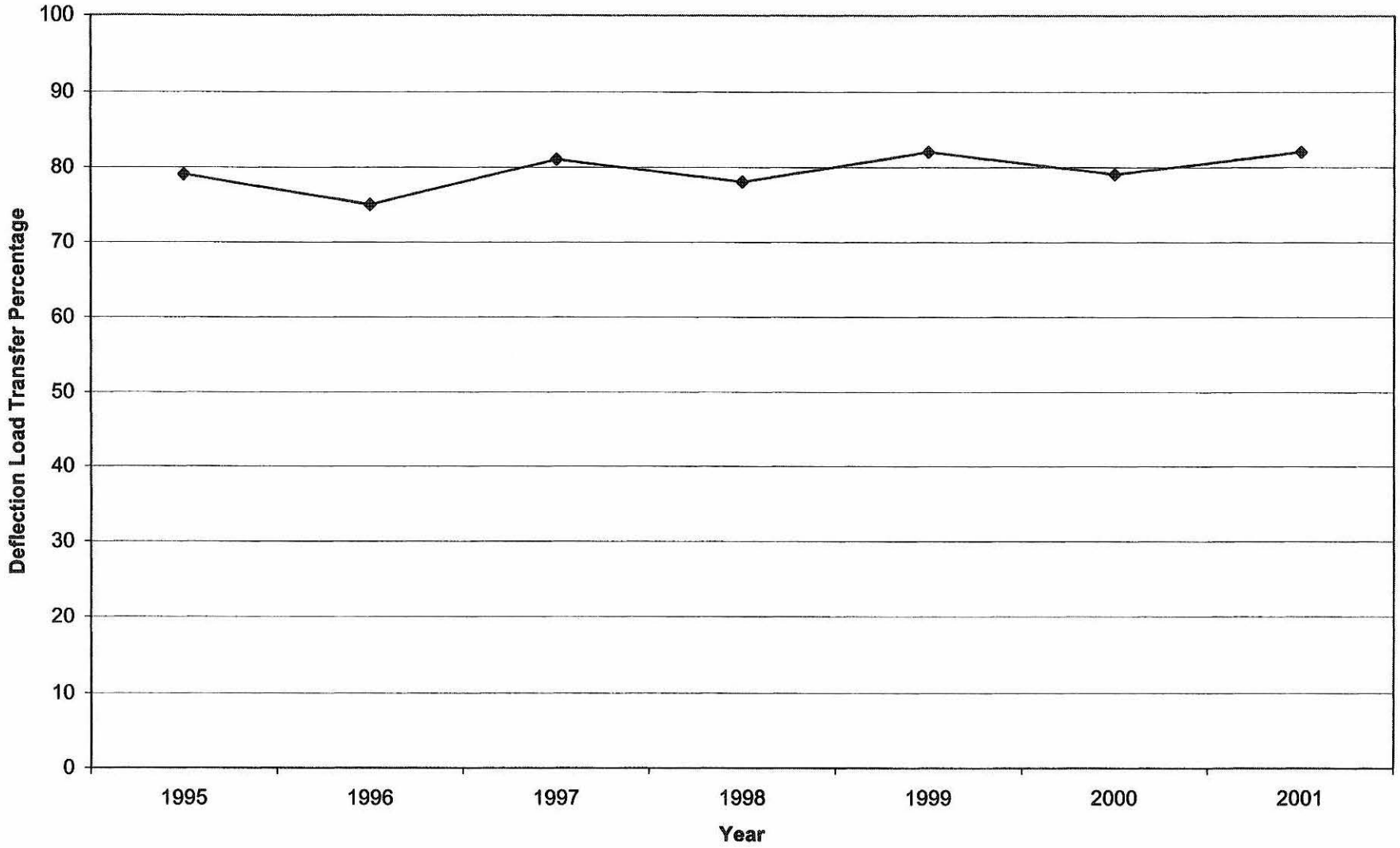

2354+00, Northbound Lane
Deflection Load Transfer Percentage
100
90
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year

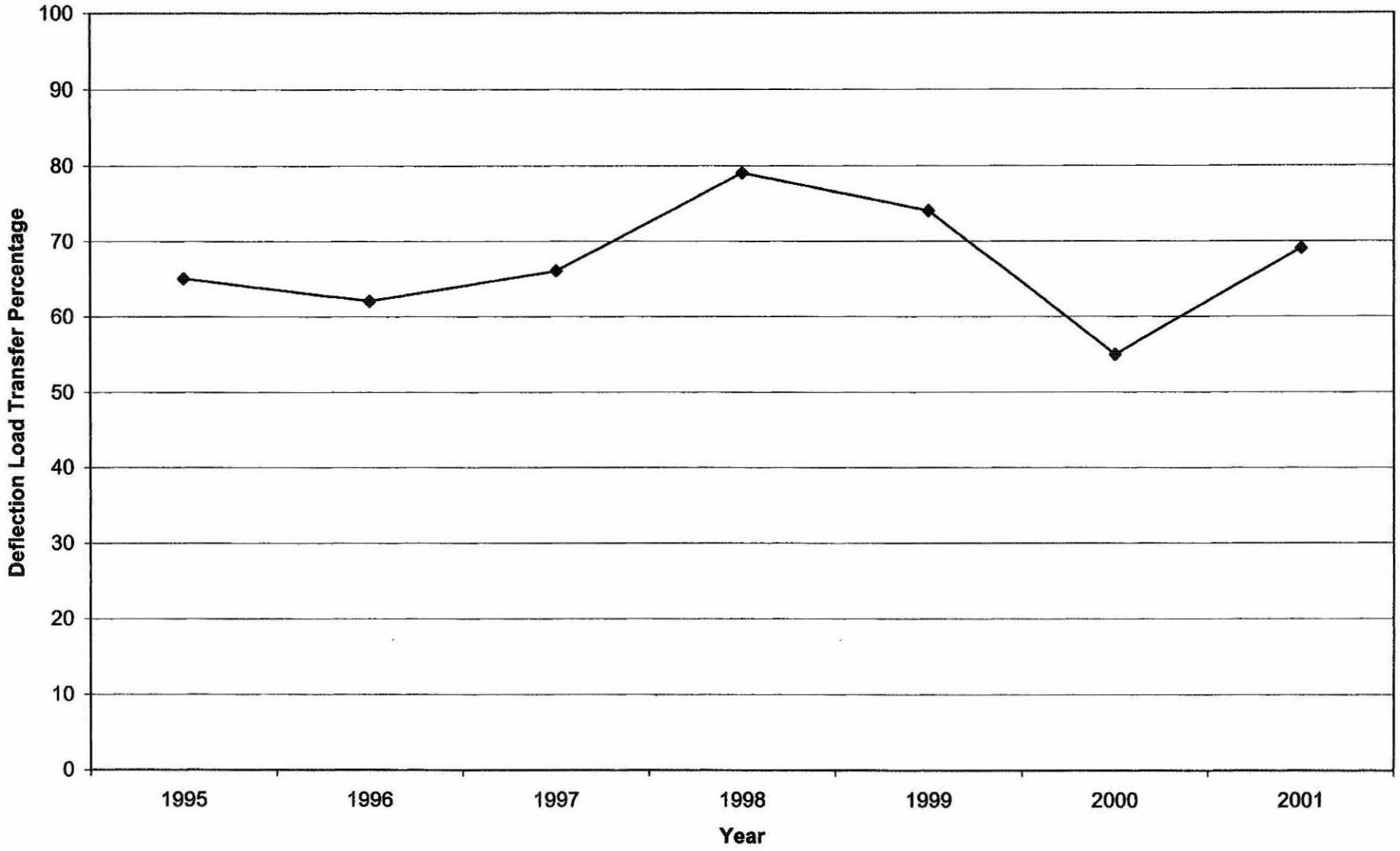

2359+50, Northbound Lane
Deflection Load Transfer Percentage
100
90
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year

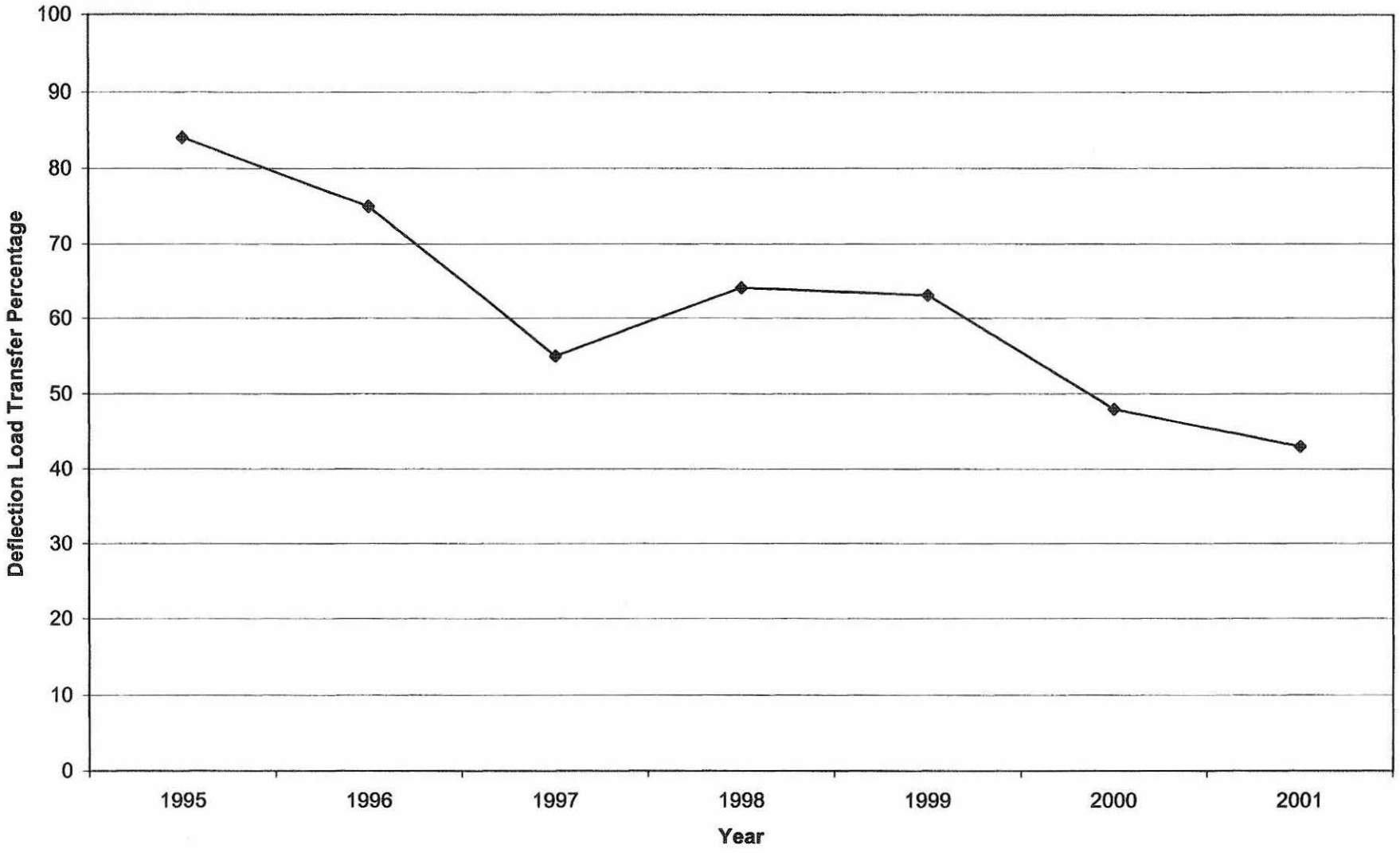

2370+00, Northbound Lane
Deflection Load Transfer Percentage
100
90
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year

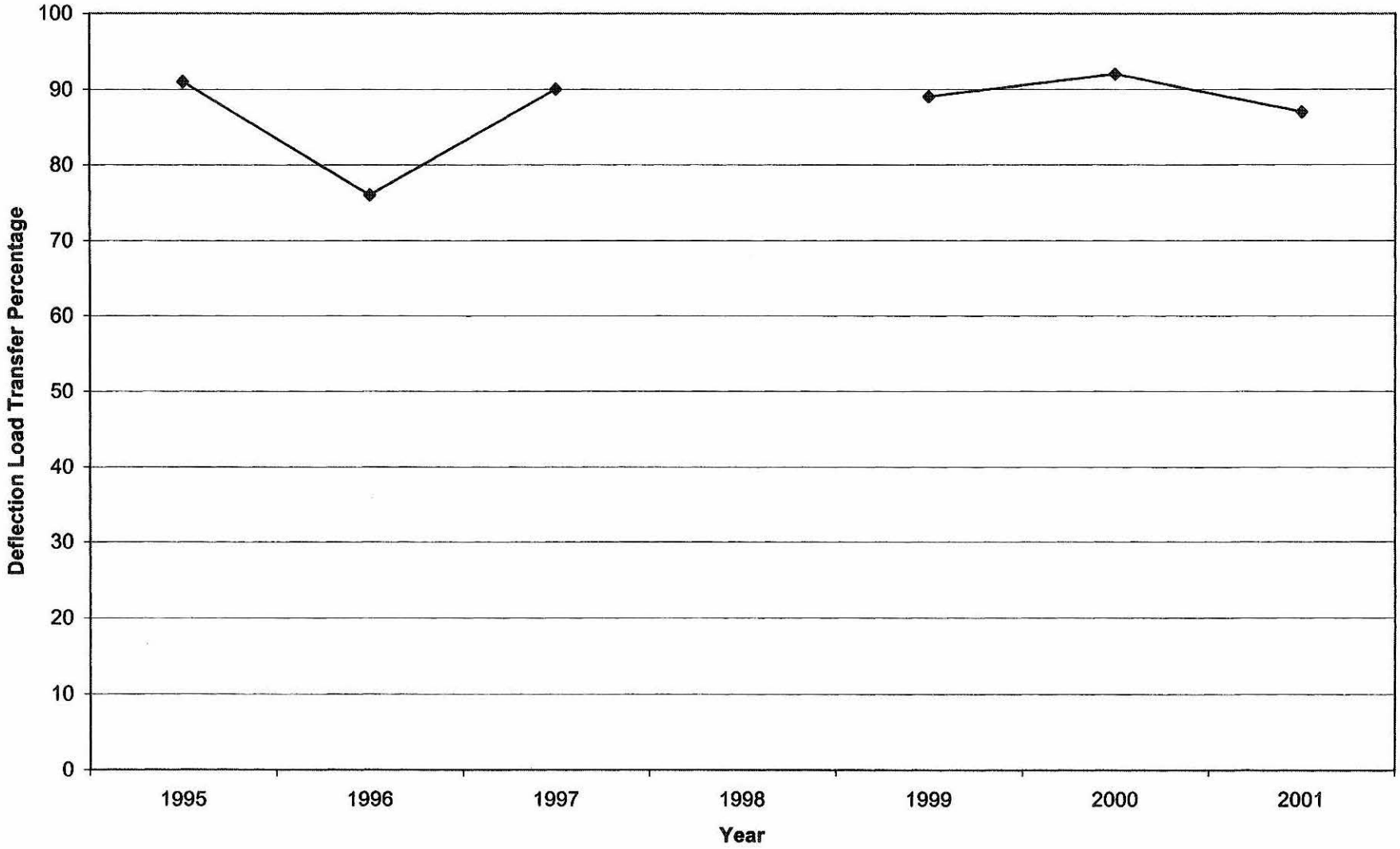

2374+50, Northbound Lane
Deflection Load Transfer Percentage
100
90
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year


2385+50, Northbound Lane
Deflection Load Transfer Percentage
100
90
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year


2391+50, Northbound Lane
Deflection Load Transfer Percentage
100
90
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year


2399+50, Northbound Lane
Deflection Load Transfer Percentage
100
90
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year


2409+50, Northbound Lane
Deflection Load Transfer Percentage
100
90
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year


2428+25, Northbound Lane
Deflection Load Transfer Percentage
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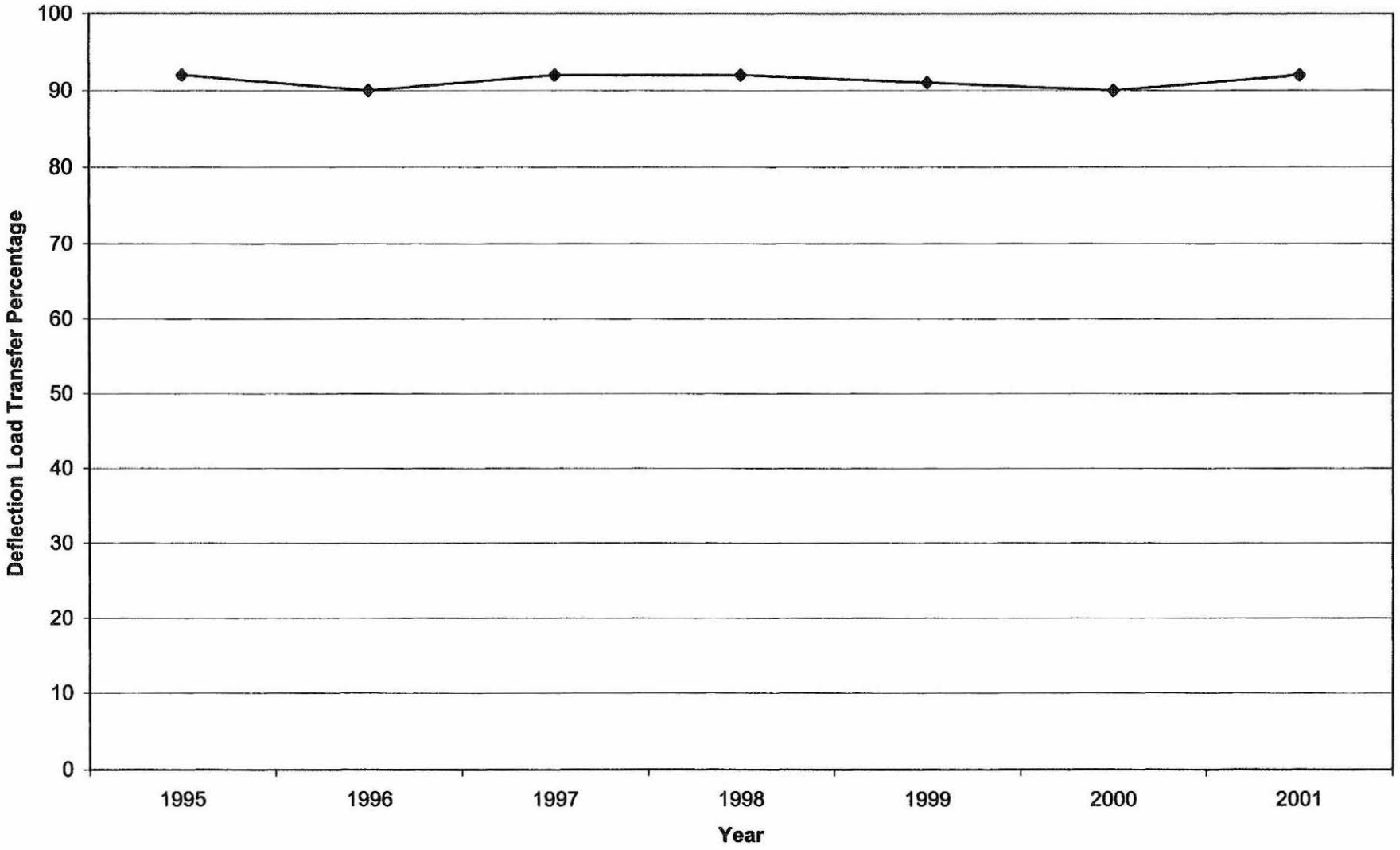
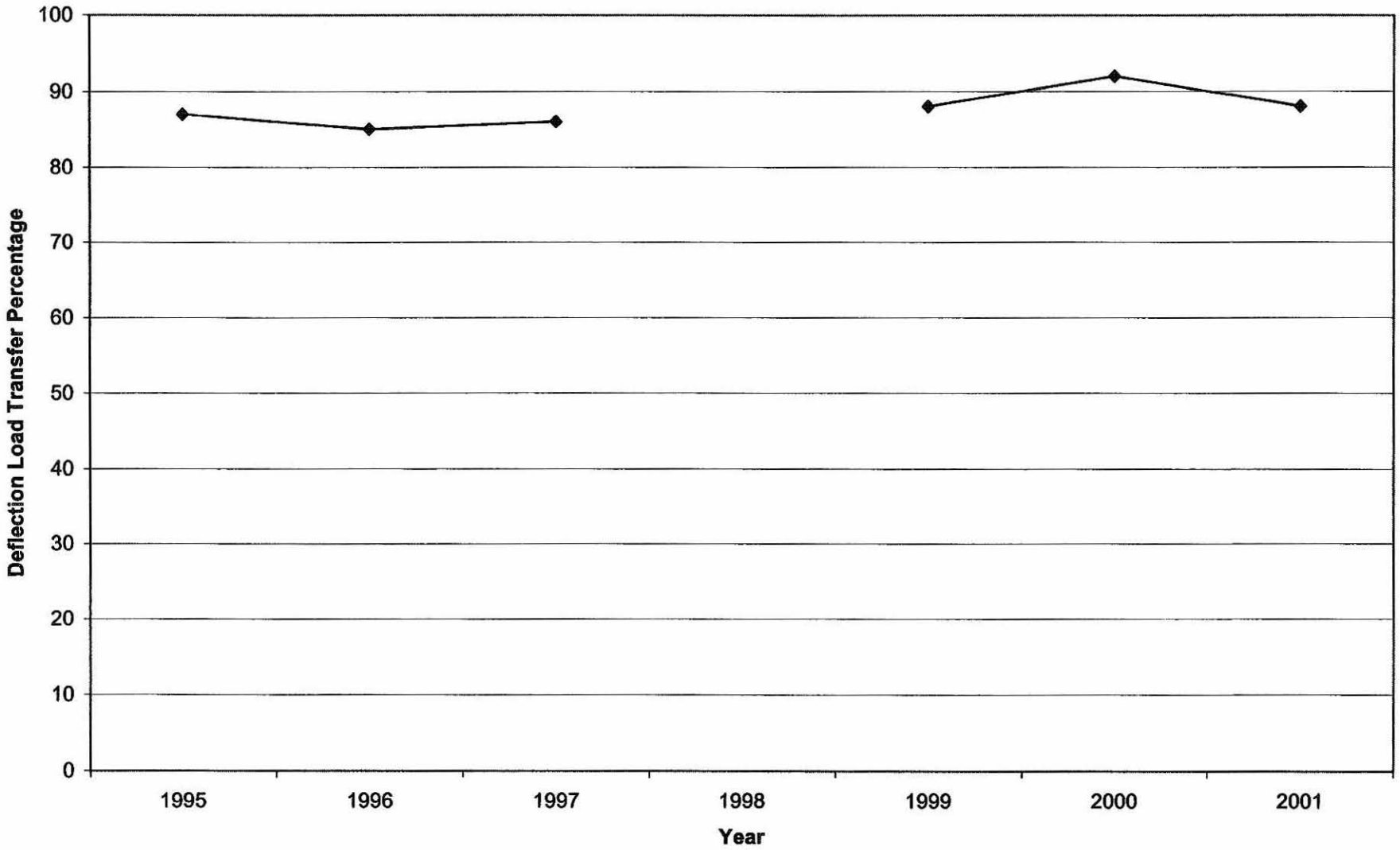
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year


2436+50, Northbound Lane
Deflection Load Transfer Percentage
100
90
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year


2445+00, Northbound Lane
Deflection Load Transfer Percentage
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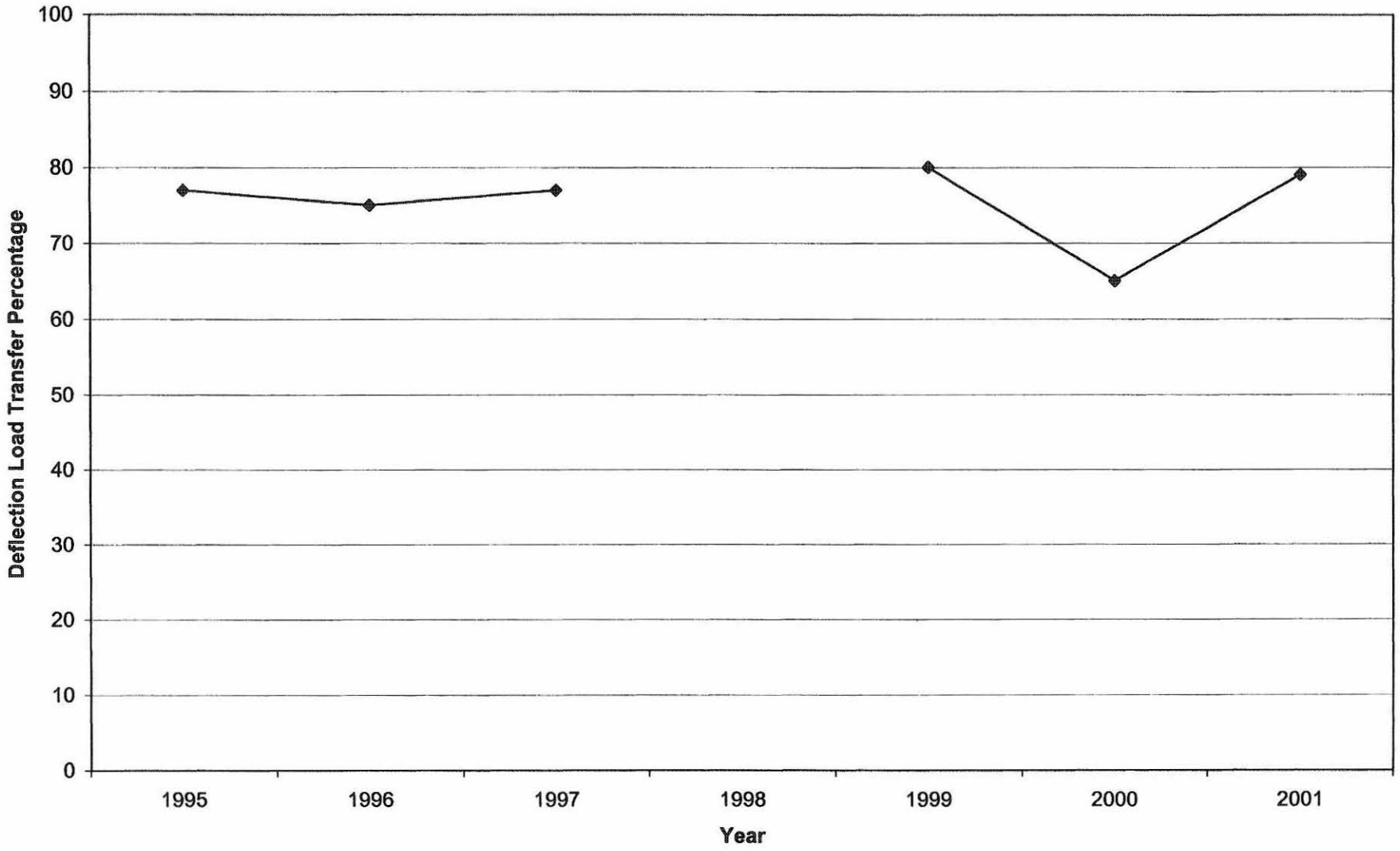
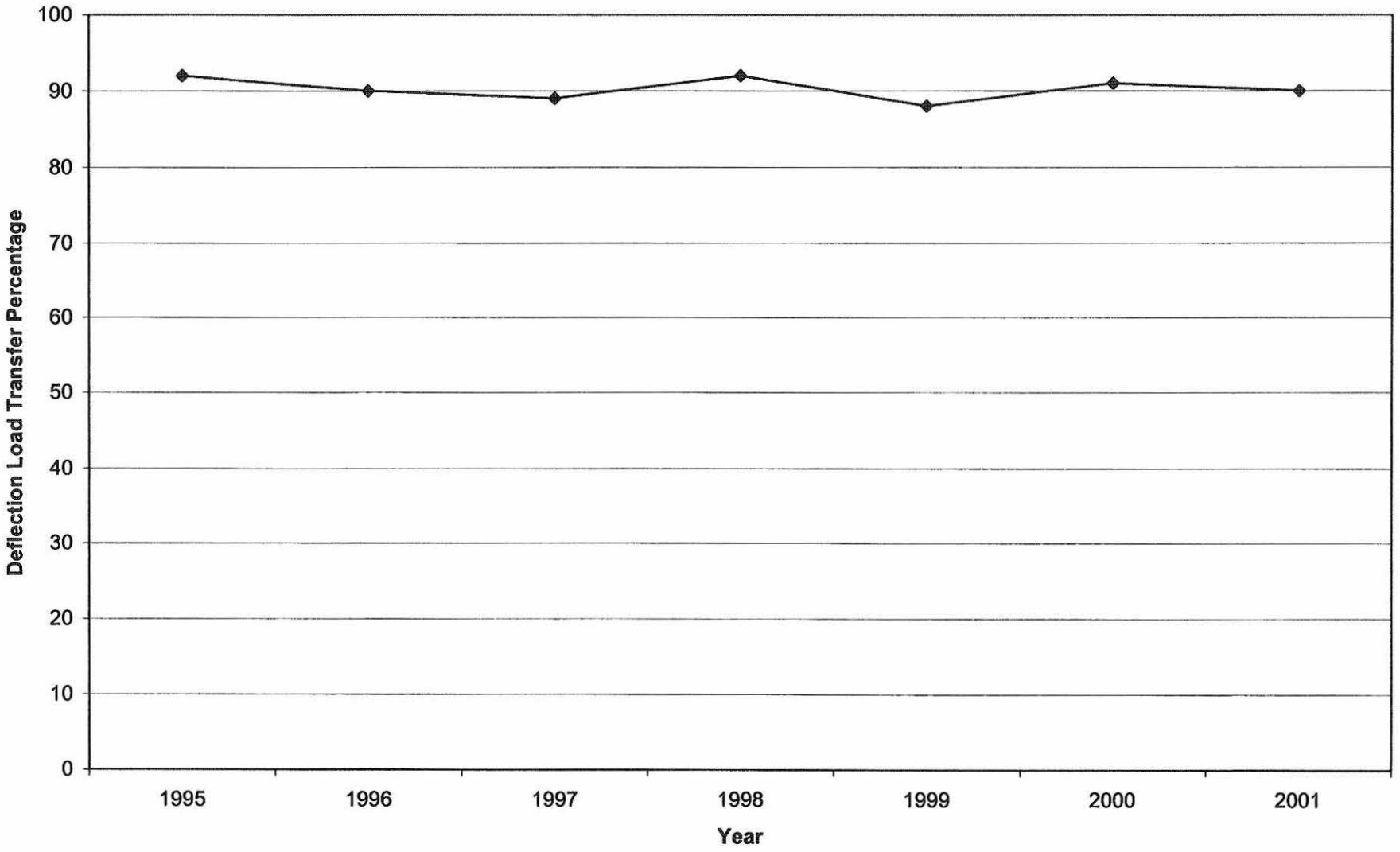
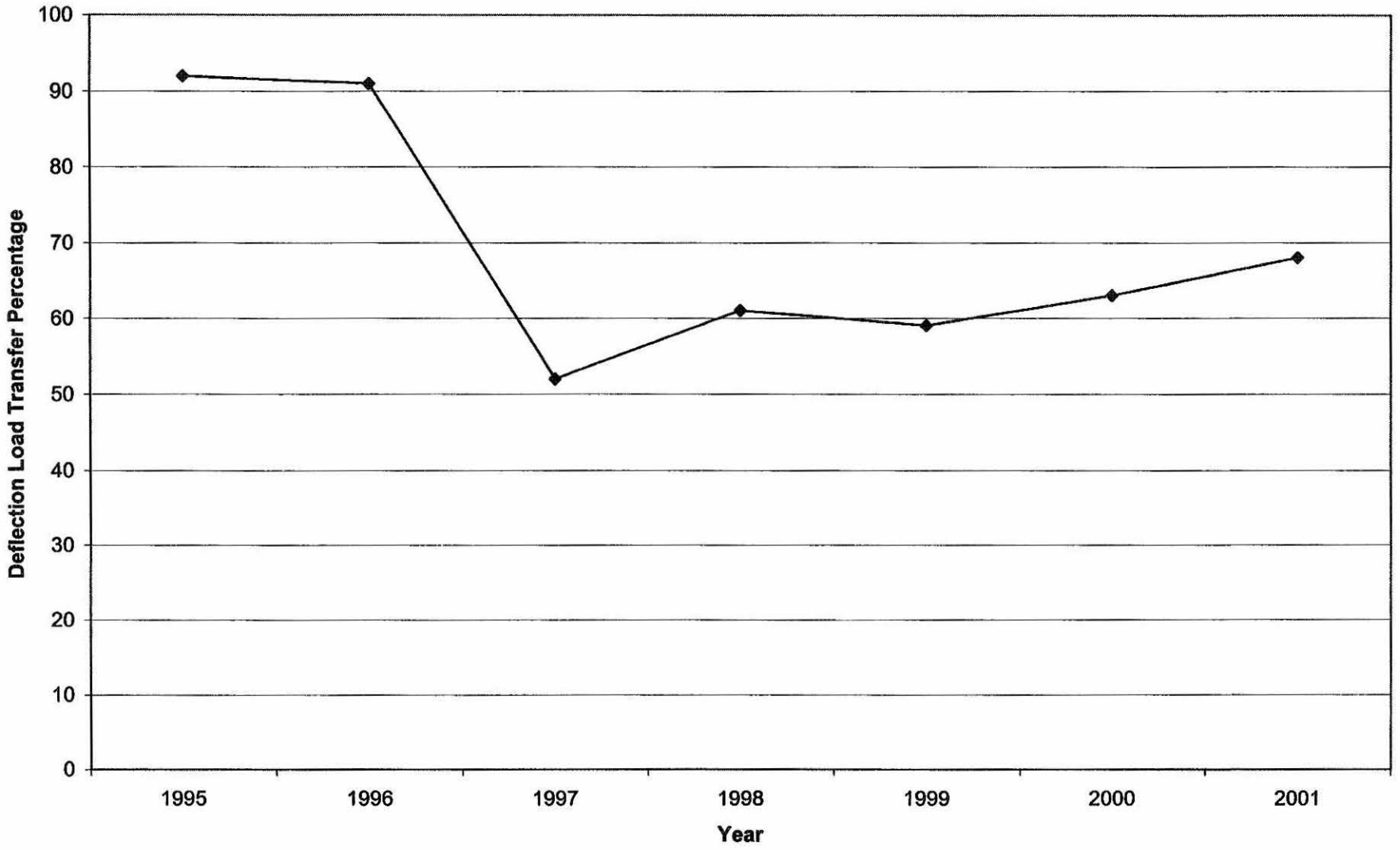
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year


2455+00, Northbound Lane
Deflection Load Transfer Percentage
100
90
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year


2465+00, Northbound Lane
Deflection Load Transfer Percentage
100
90
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year


2475+50, Northbound Lane
Deflection Load Transfer Percentage
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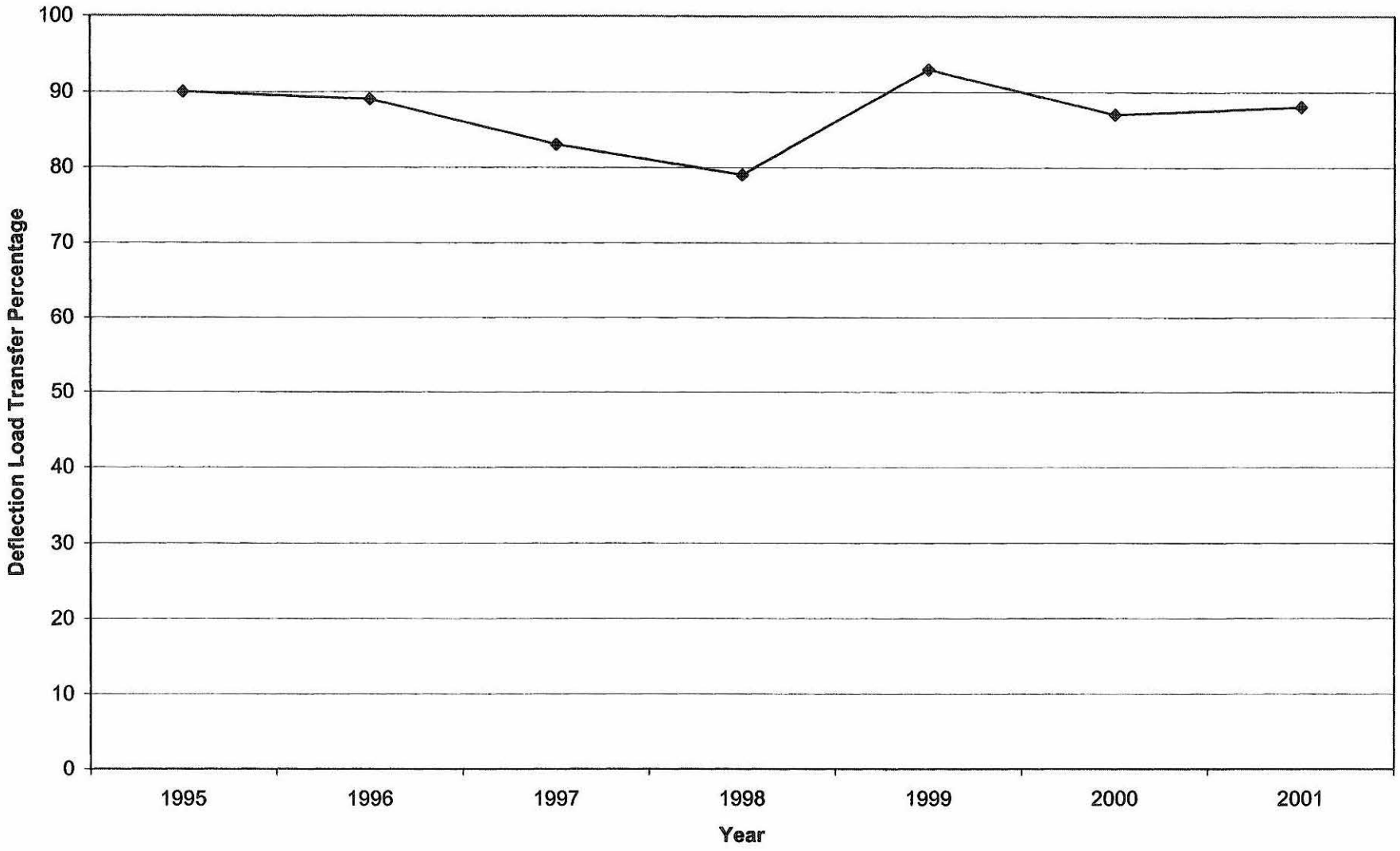
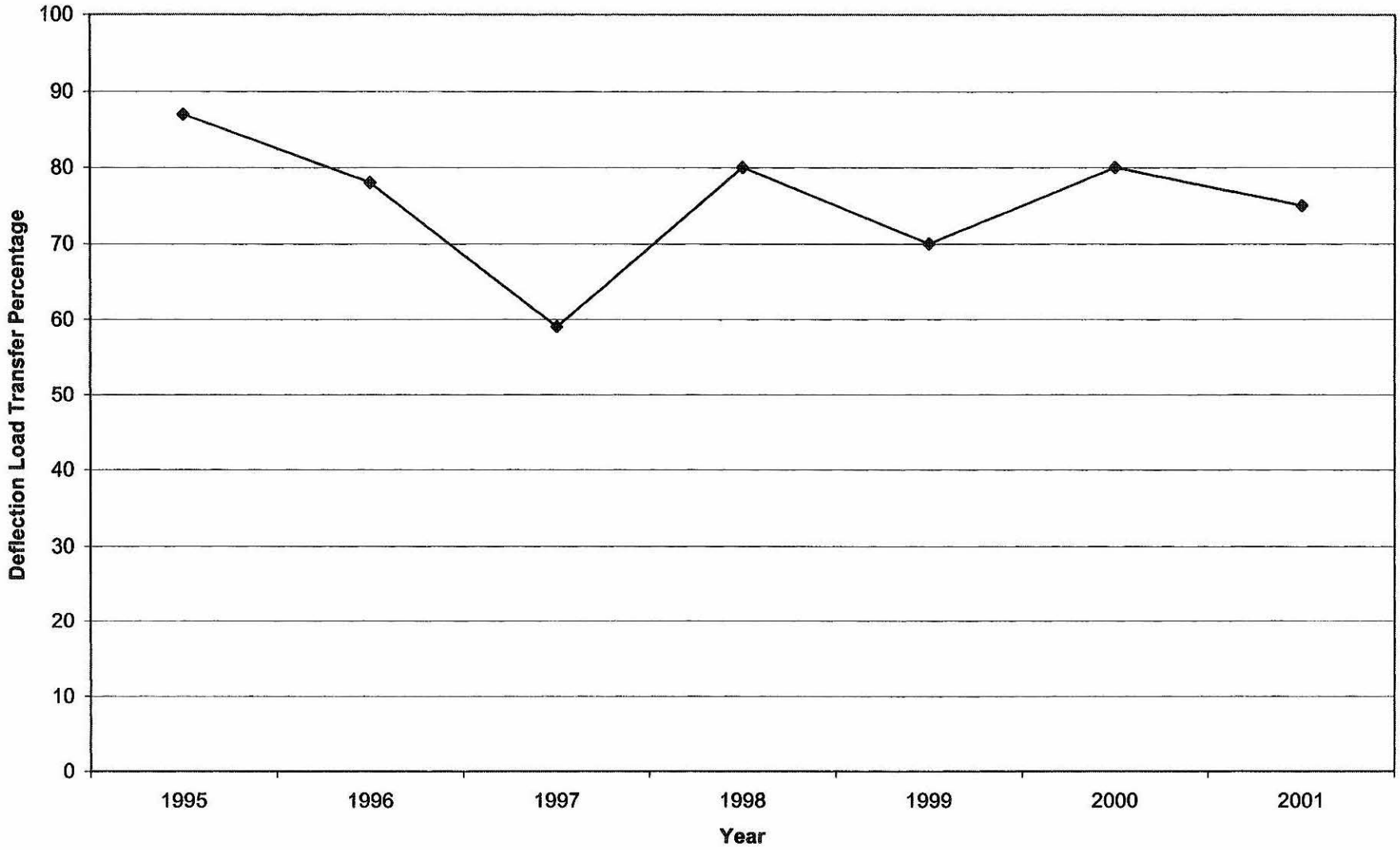
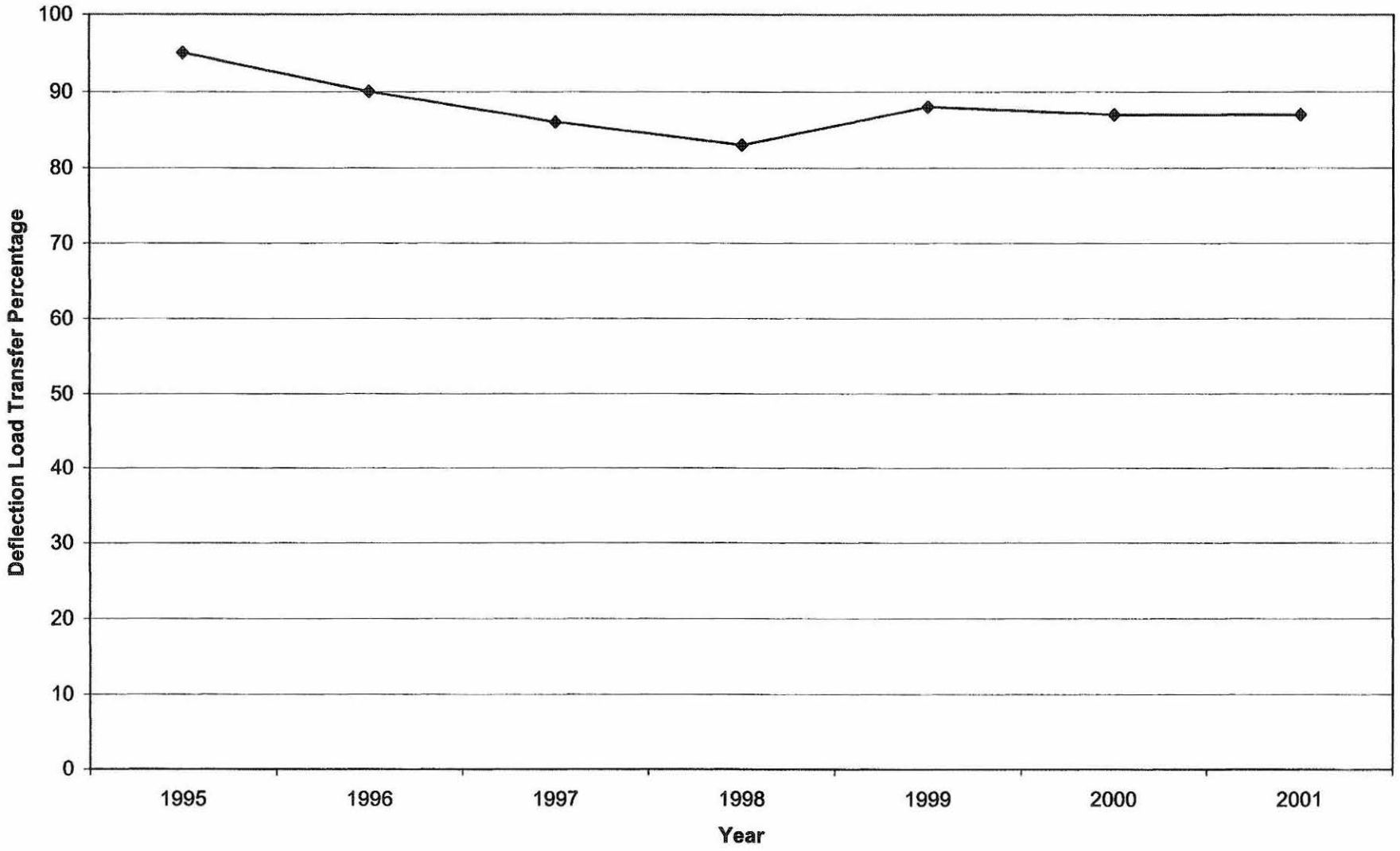
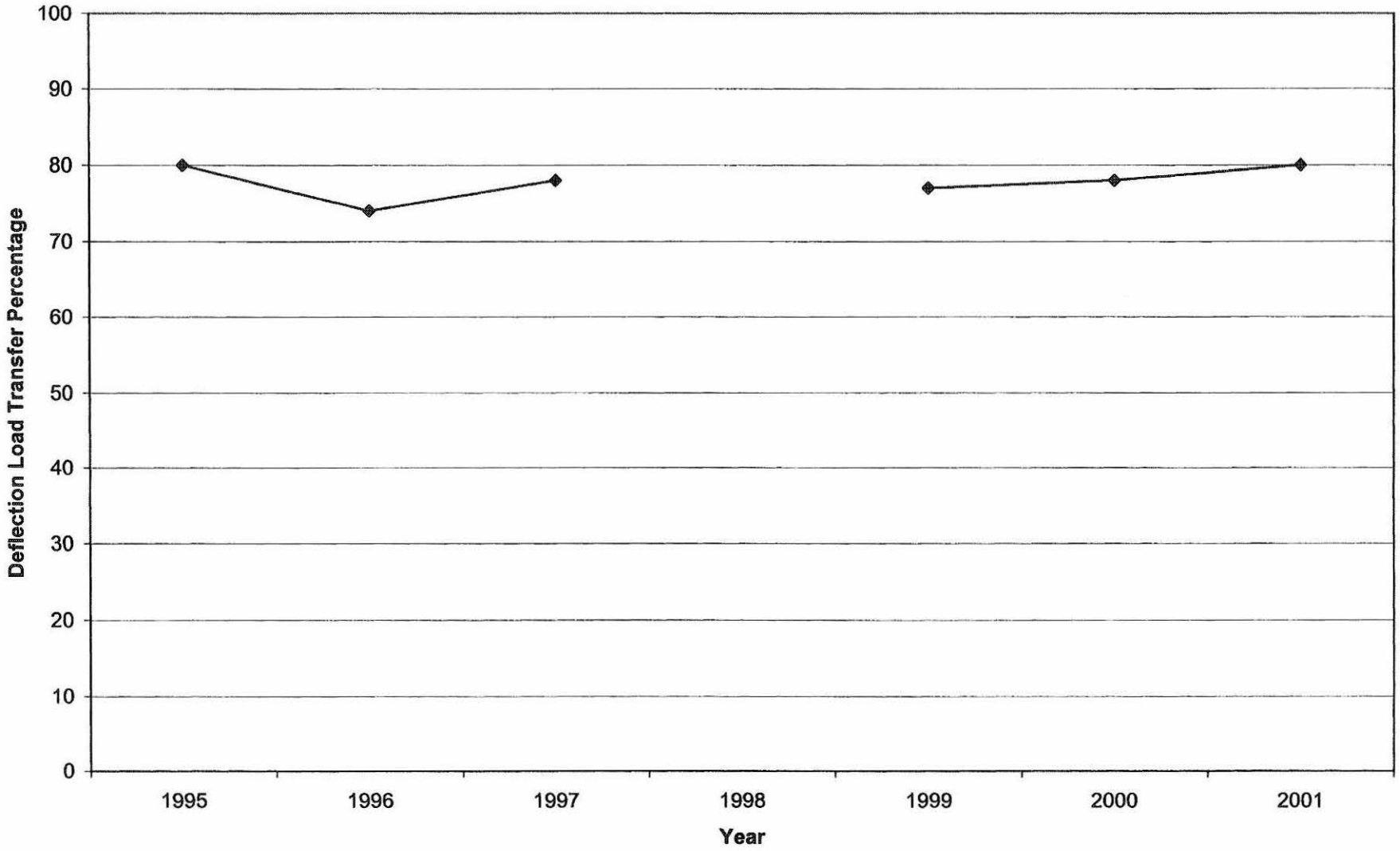
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year

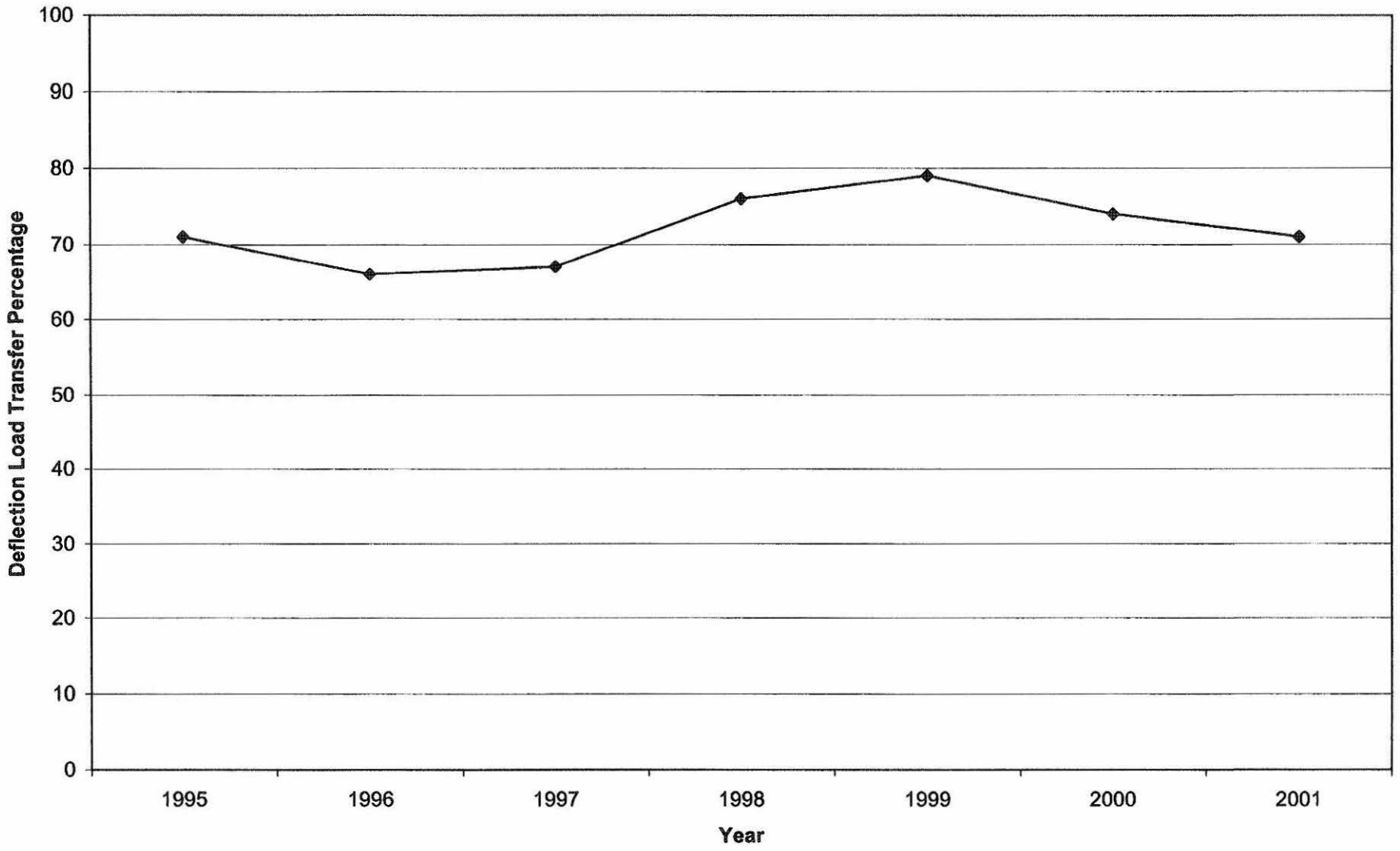

2485+00, Northbound Lane
Deflection Load Transfer Percentage
100
90
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year


2494+50, Northbound Lane
Deflection Load Transfer Percentage
100
90
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year


2502+00, Northbound Lane
Deflection Load Transfer Percentage
100
90
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year

2620+00, Northbound Lane




2630+00, Northbound Lane
Deflection Load Transfer Percentage
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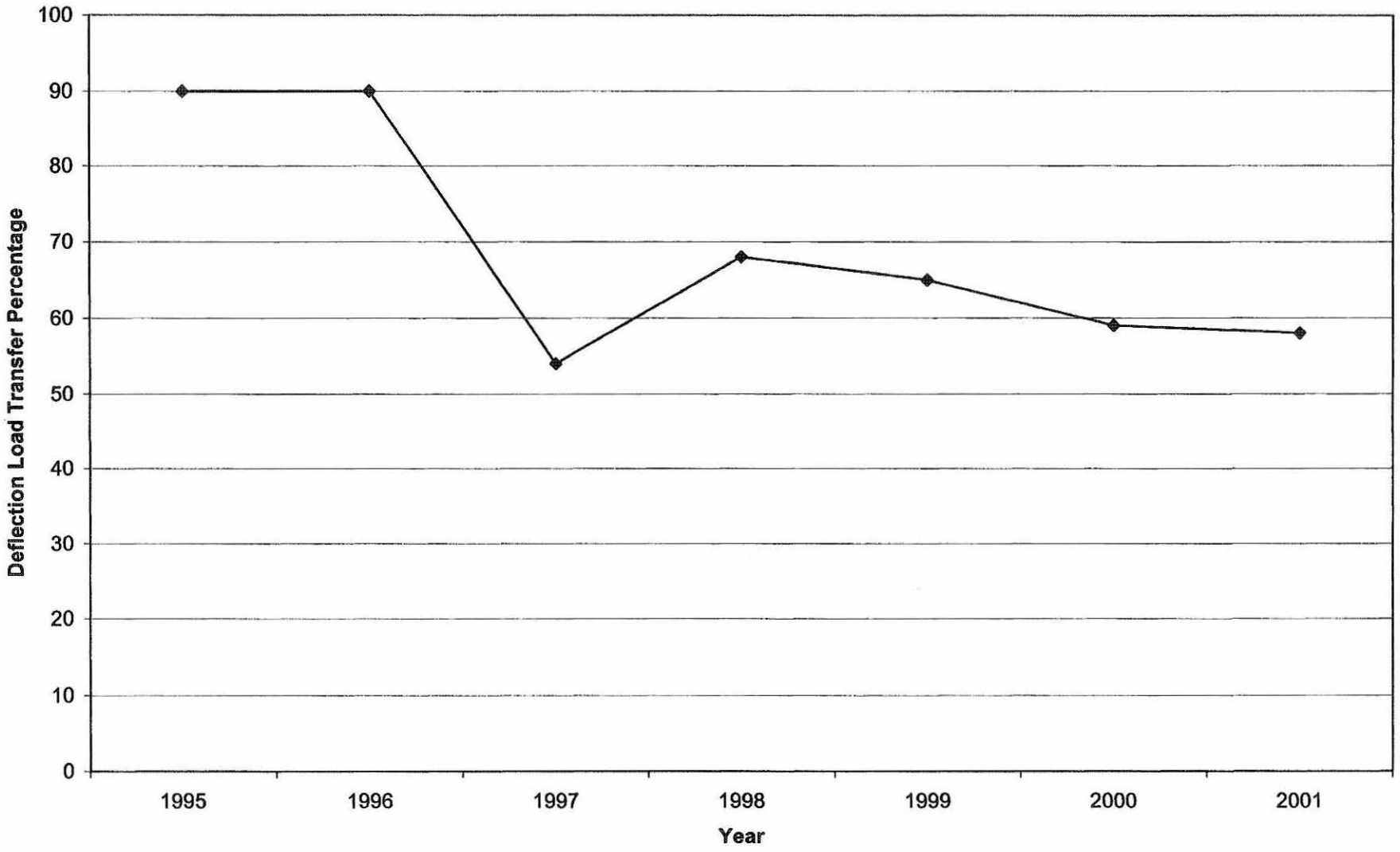
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year


2635+50, Northbound Lane
Deflection Load Transfer Percentage
100
90
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year


2650+00, Northbound Lane
Deflection Load Transfer Percentage
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60
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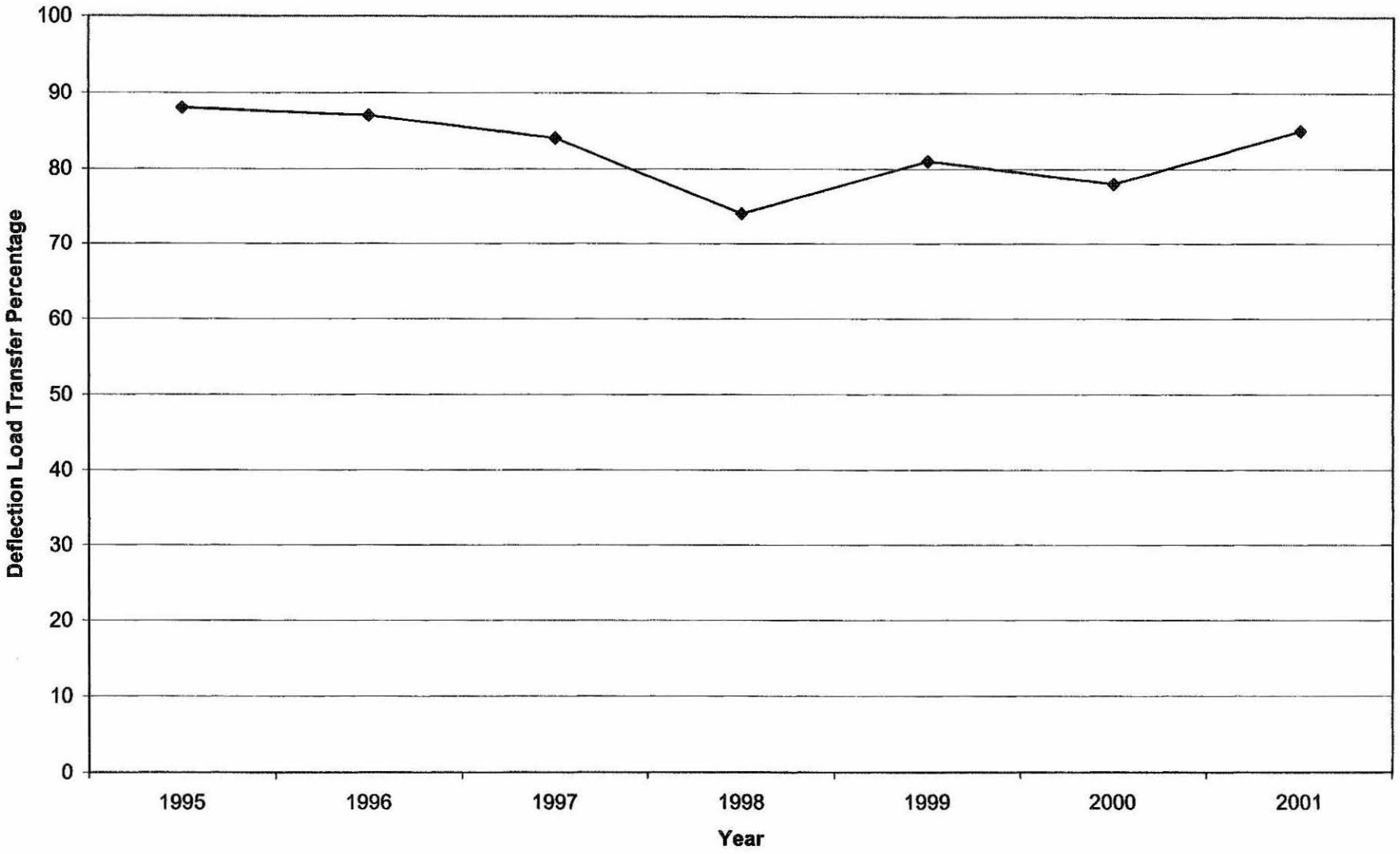
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year


2659+50, Northbound Lane
Deflection Load Transfer Percentage
100
90
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1995
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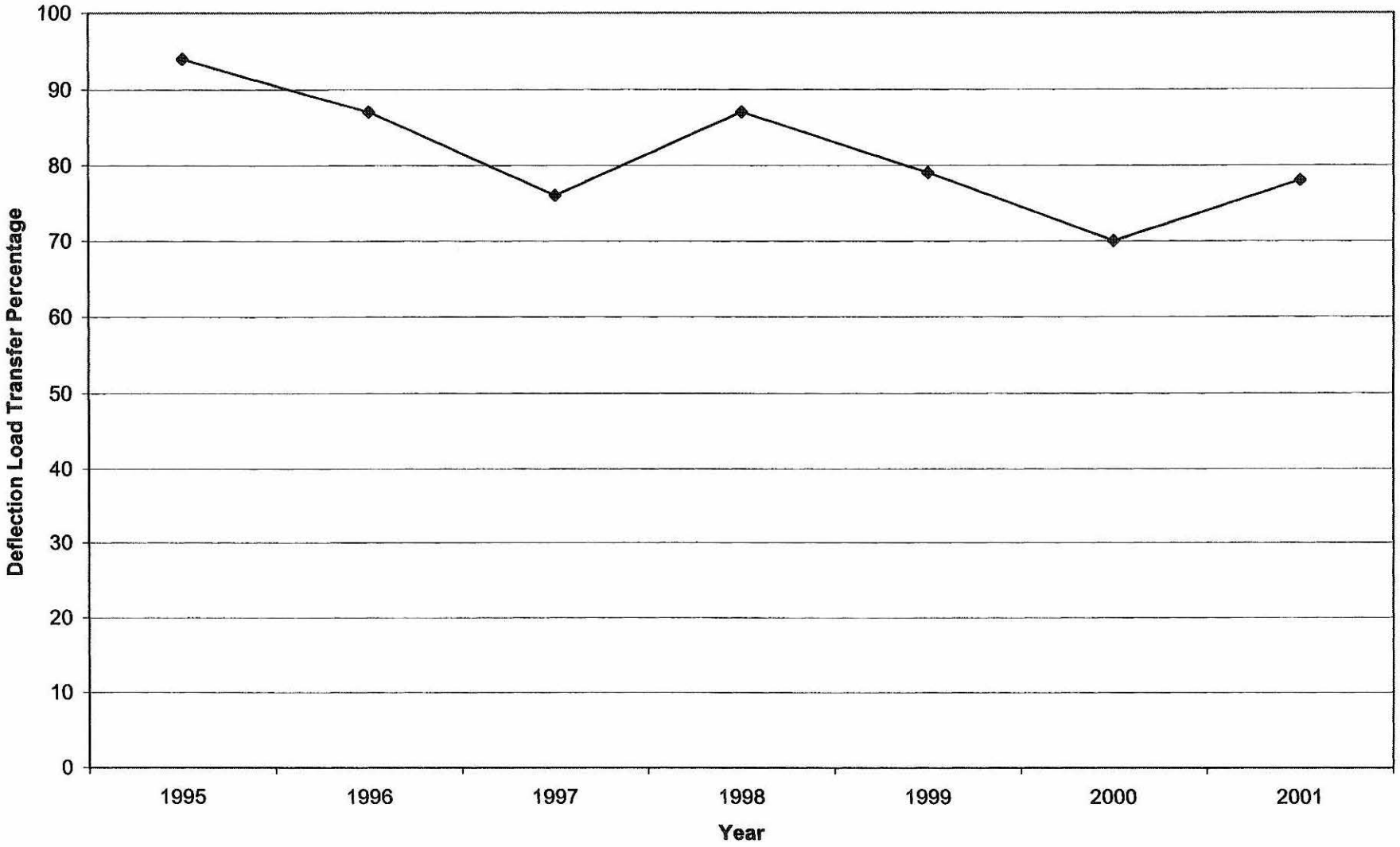
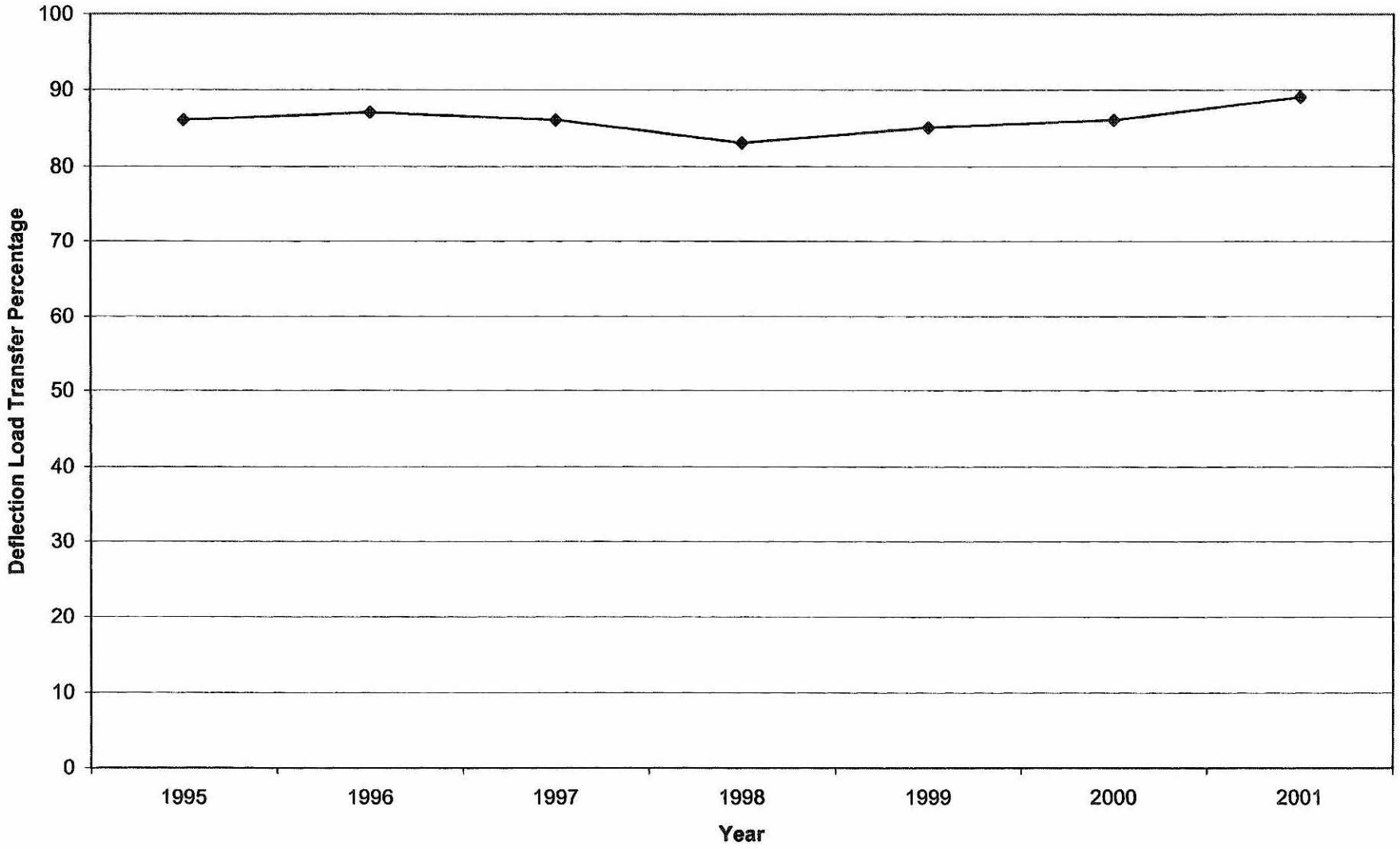
1997
1998
1999
2000
2001
Year

2685+50, Northbound Lane




2694+50, Northbound Lane
Deflection Load Transfer Percentage
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40
30
20
10
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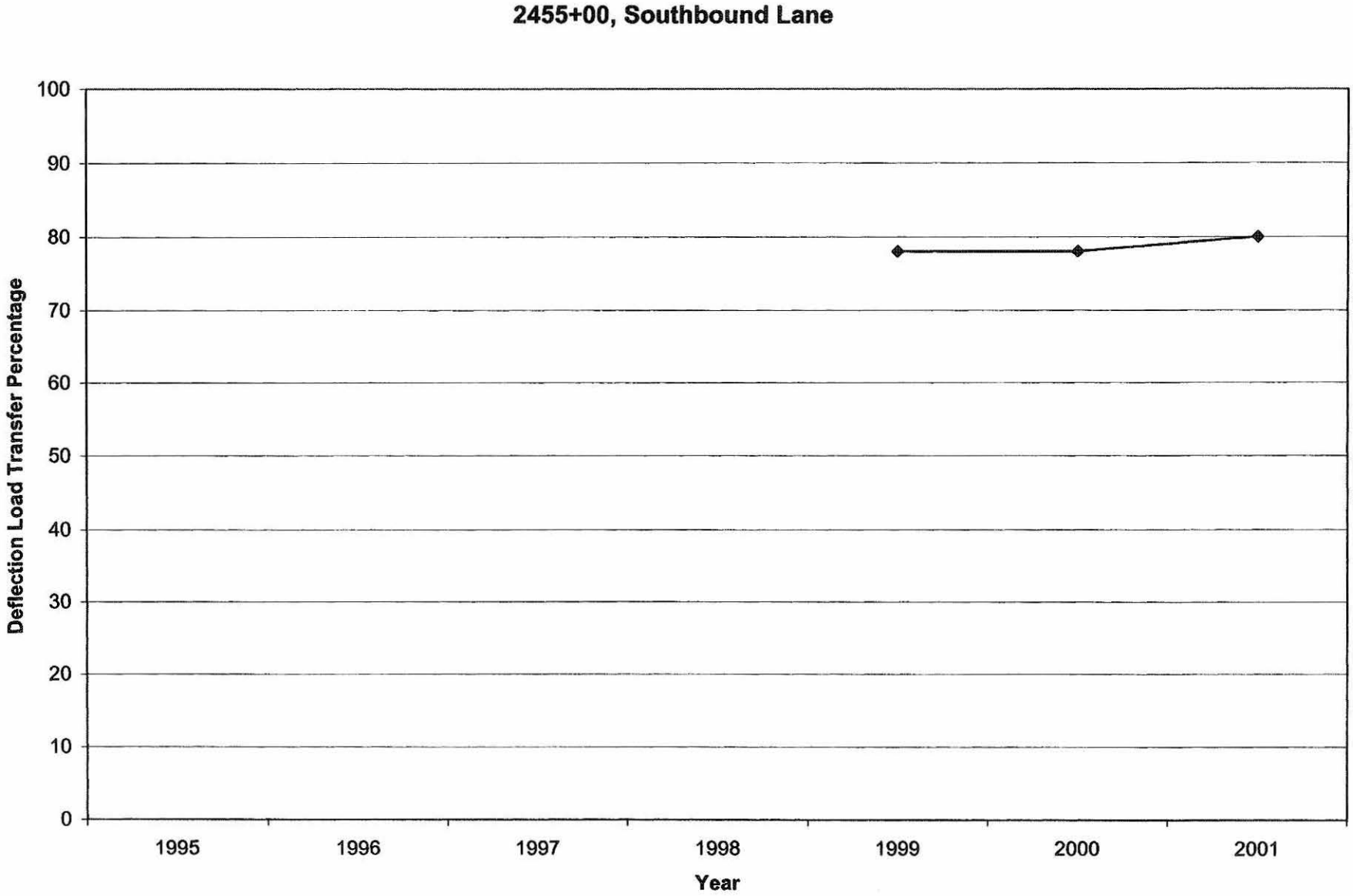
1995
1996
1997
1998
1999
2000
2001
Year


2455+00, Southbound Lane
Deflection Load Transfer Percentage
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30
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1995
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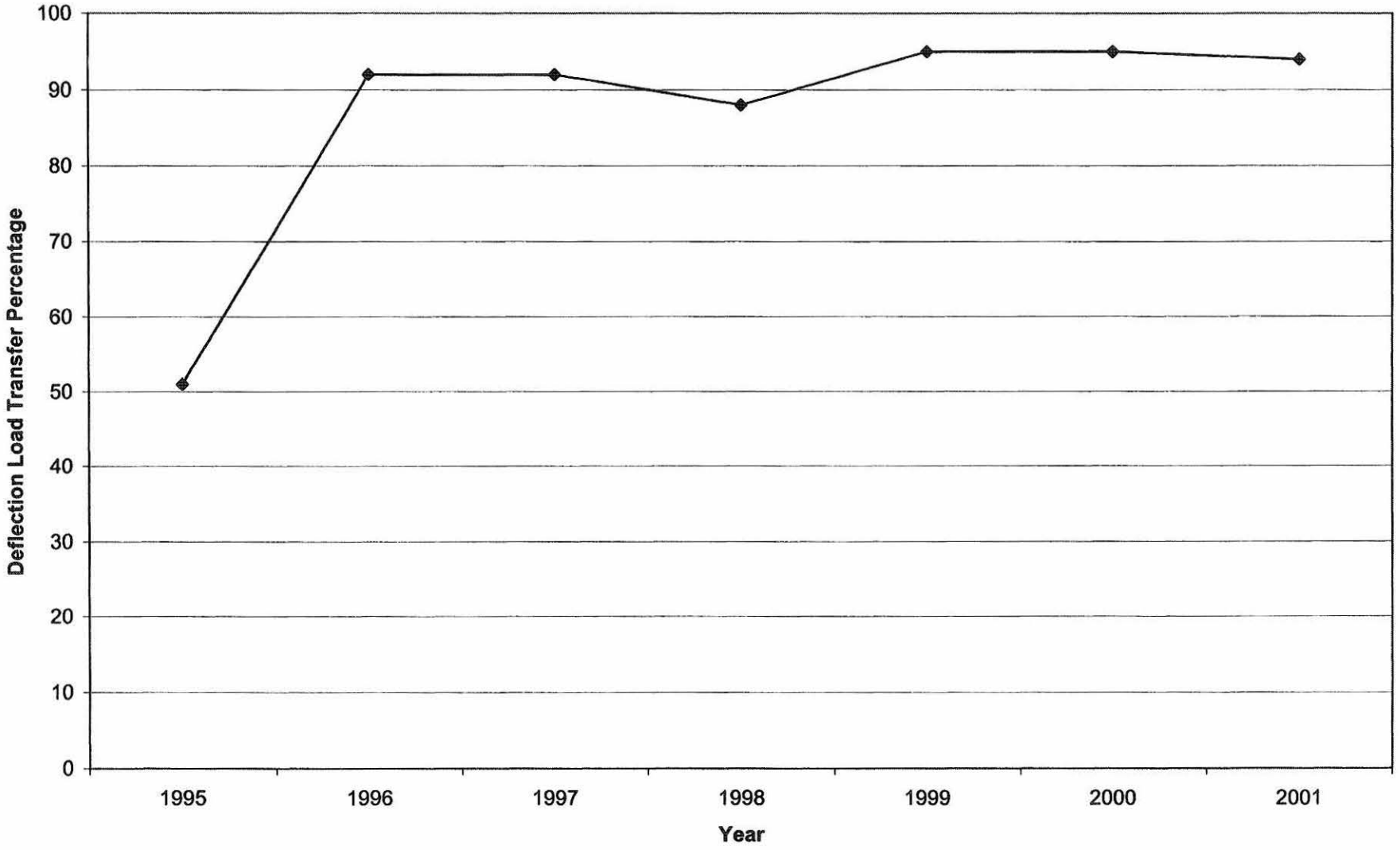
1998
1999
2000
2001
Year


2534+00, Southbound Lane
Deflection Load Transfer Percentage
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40
30
20
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0
1995
1996
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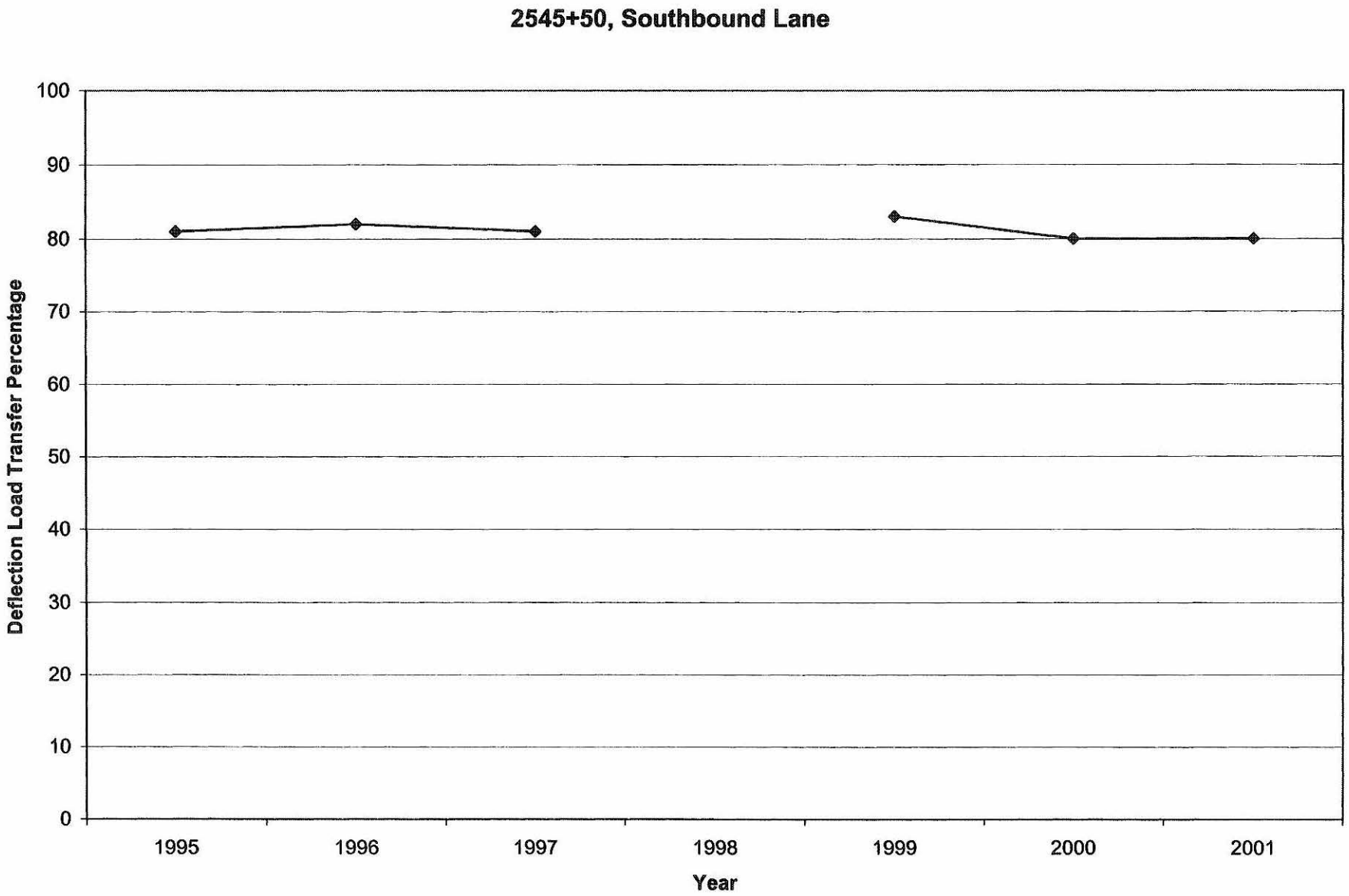
1998
1999
2000
2001
Year


2545+50, Southbound Lane
Deflection Load Transfer Percentage
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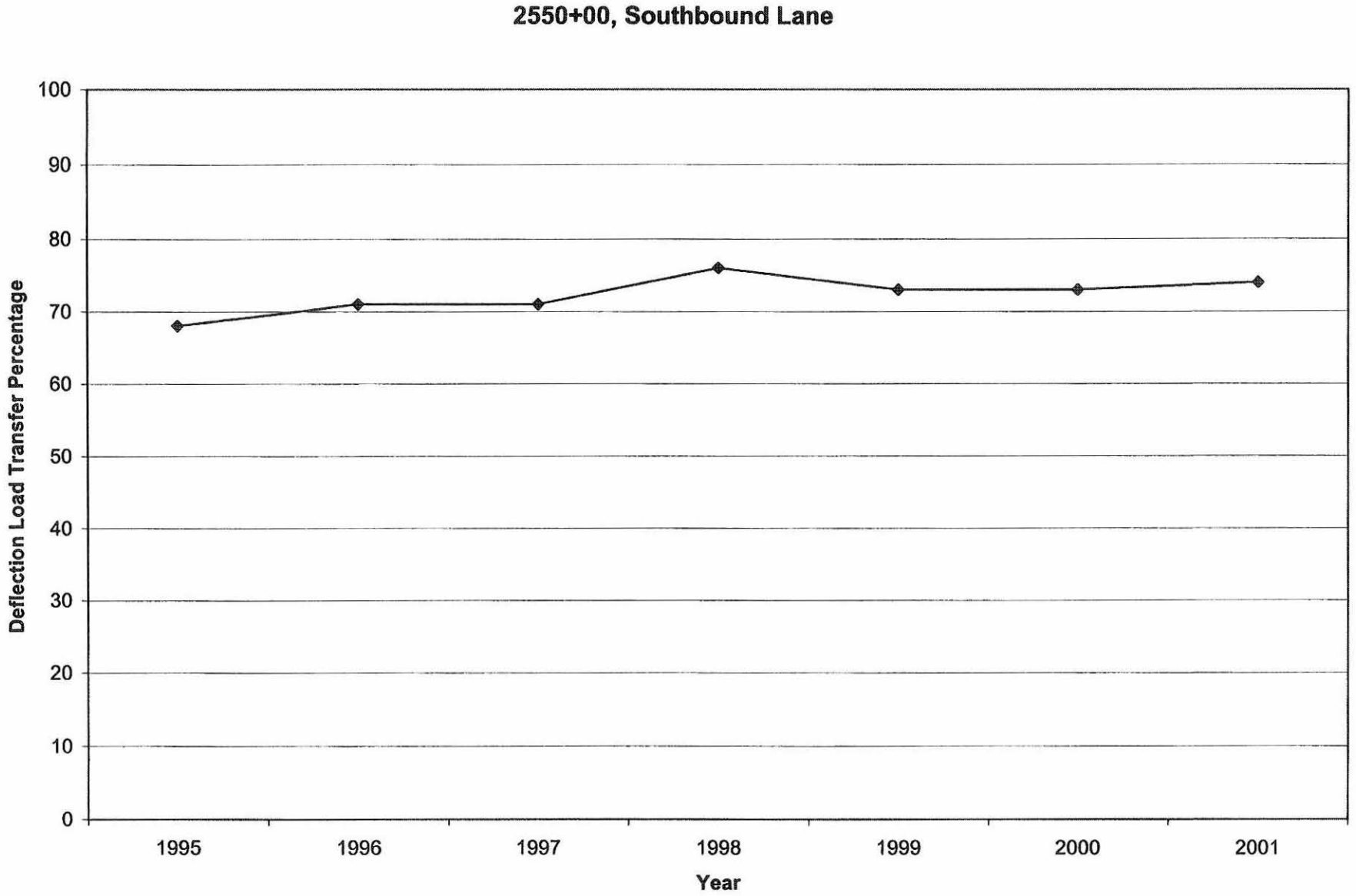
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year


2550+00, Southbound Lane
Deflection Load Transfer Percentage
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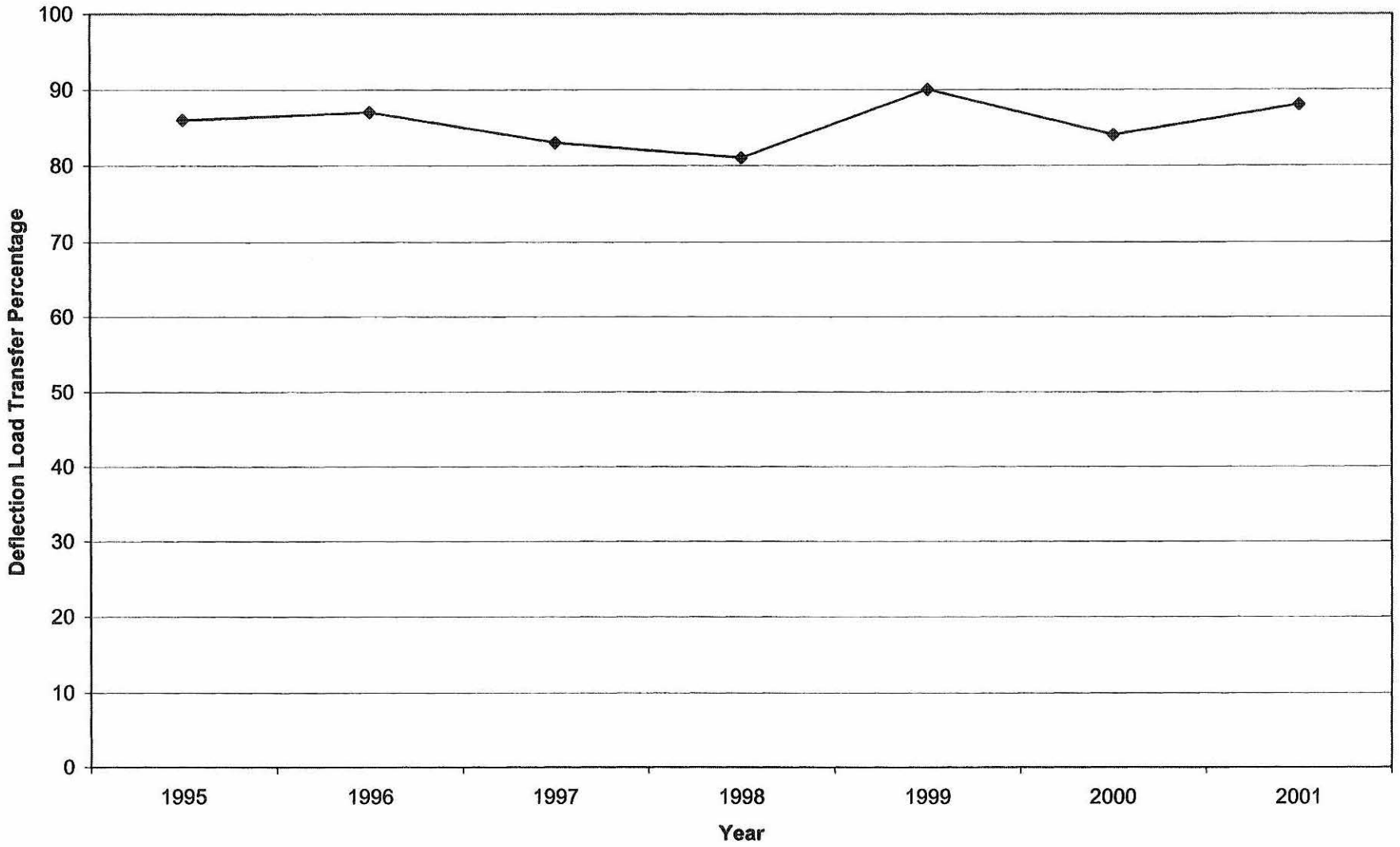
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year


2560+00, Southbound Lane
Deflection Load Transfer Percentage
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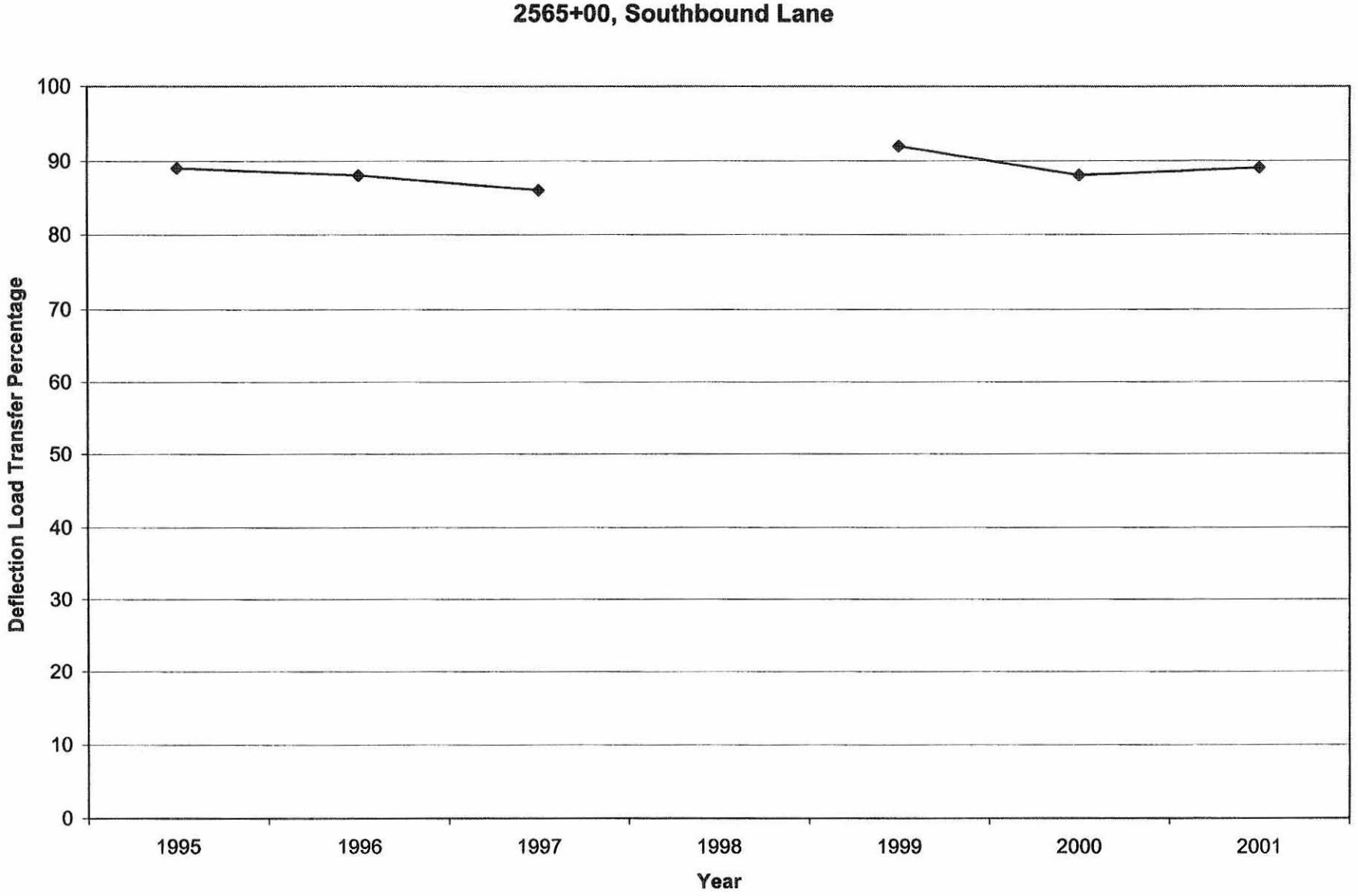
90
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year


2565+00, Southbound Lane
Deflection Load Transfer Percentage
100
90
80
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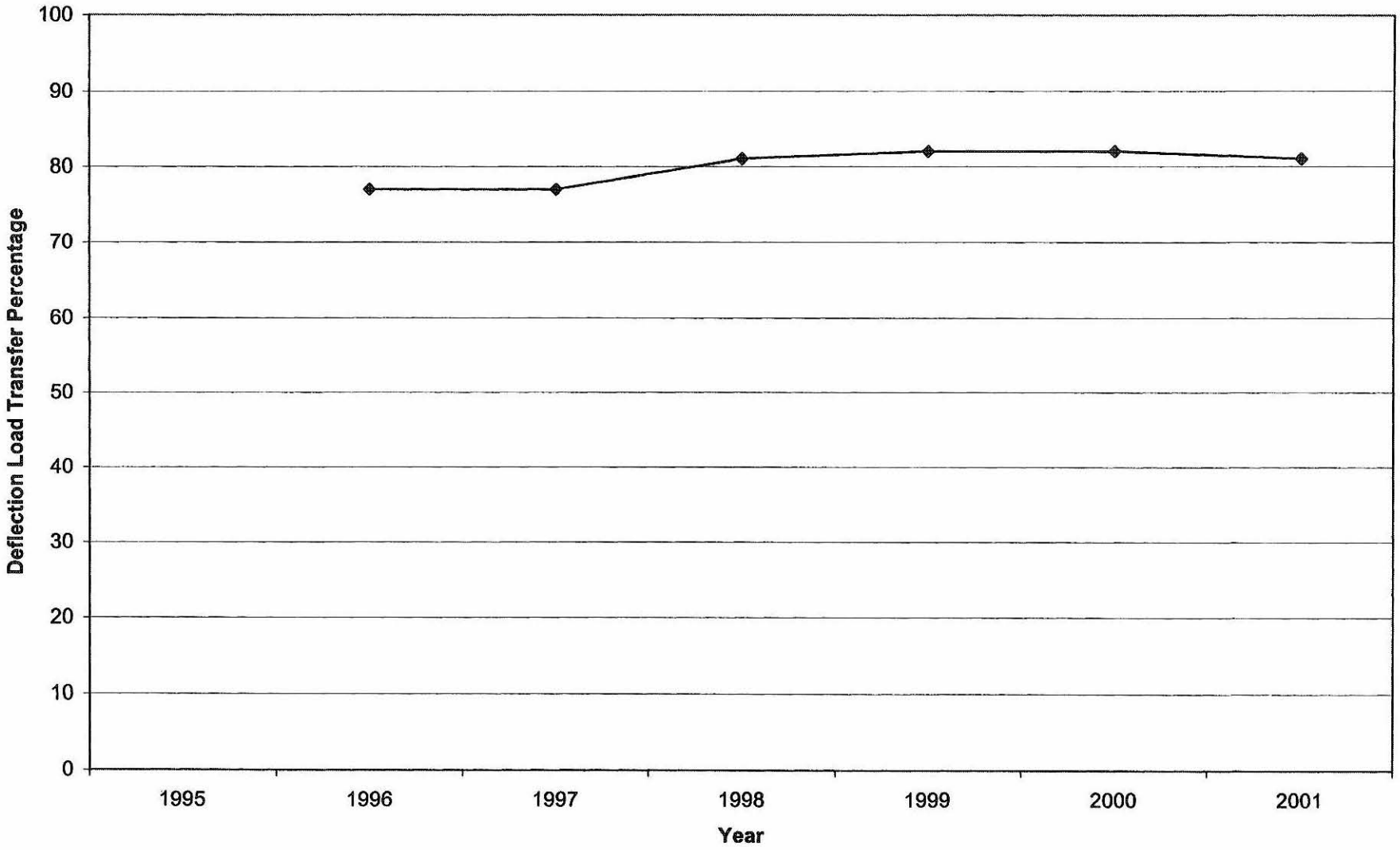
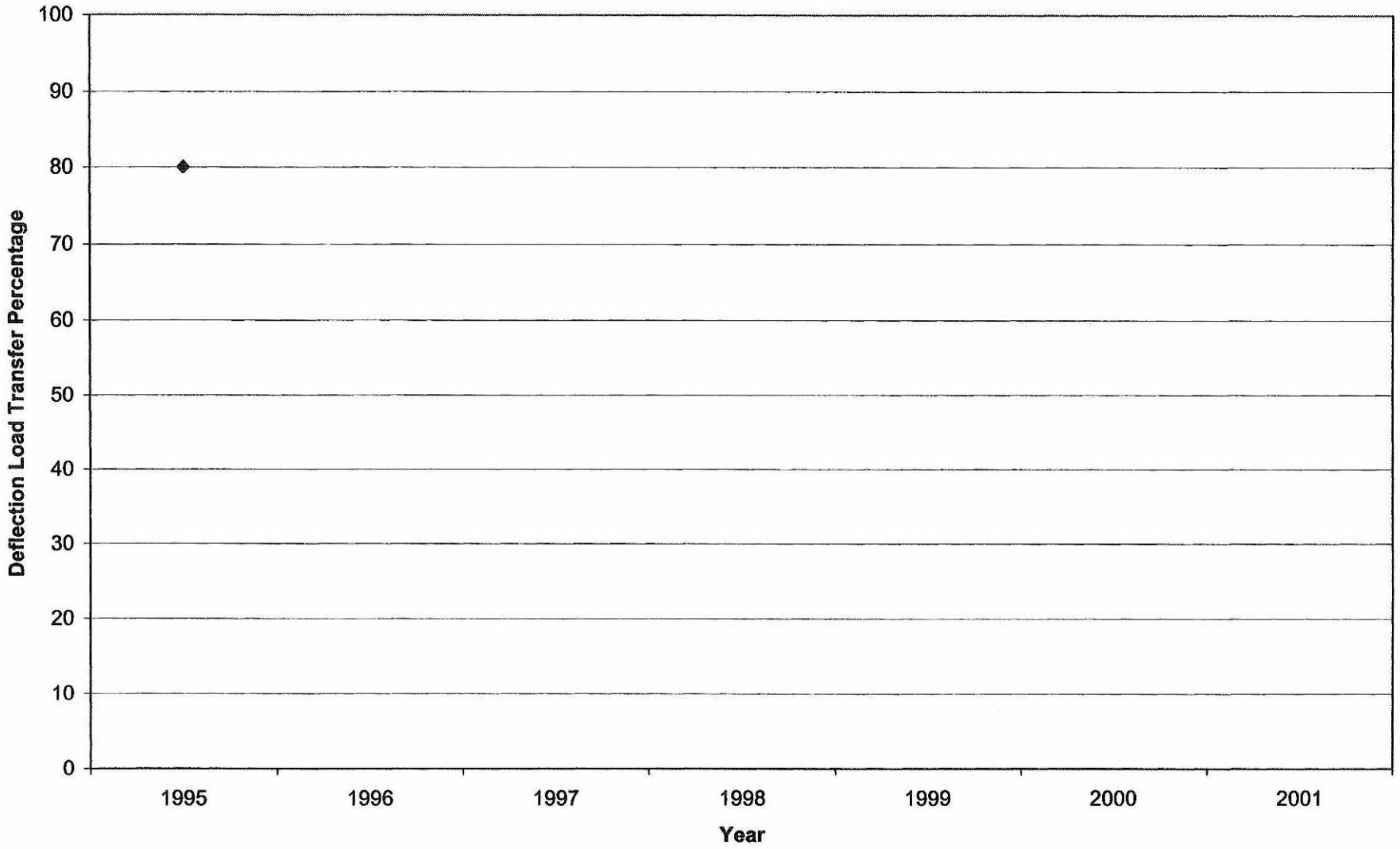
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year

2574+00, Southbound Lane




2575+00, Southbound Lane
Deflection Load Transfer Percentage
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90
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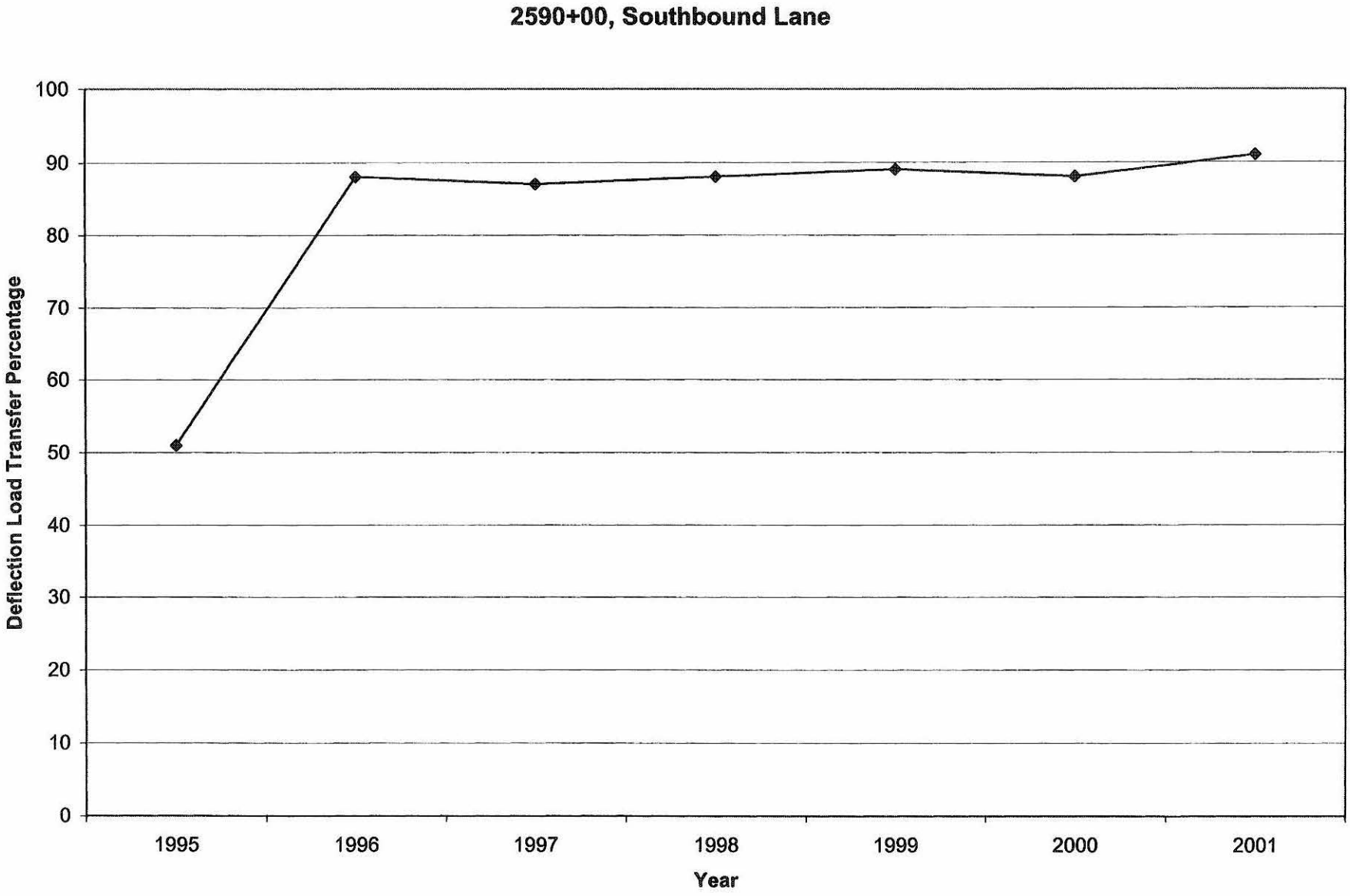
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year


2590+00, Southbound Lane
Deflection Load Transfer Percentage
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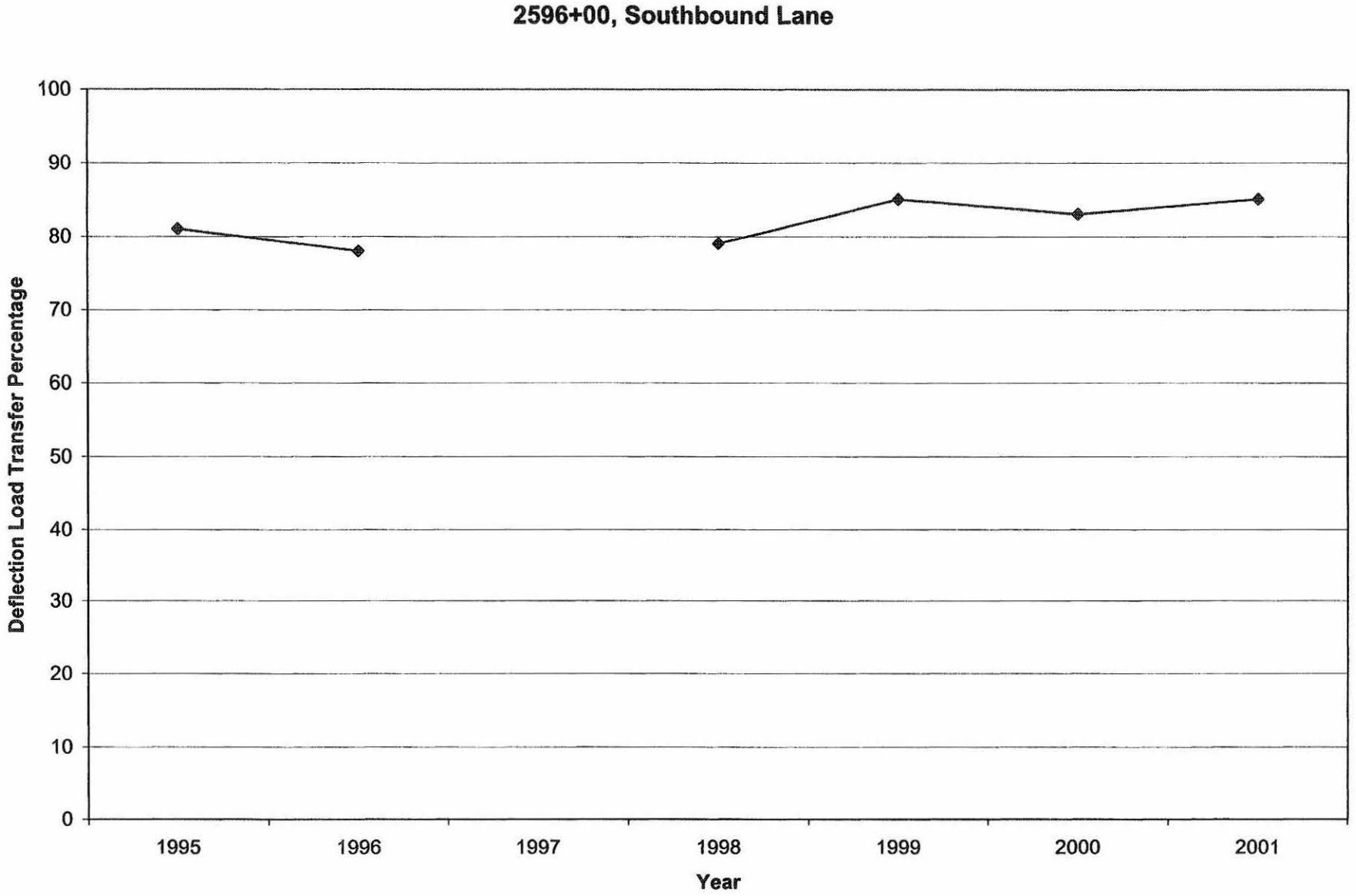
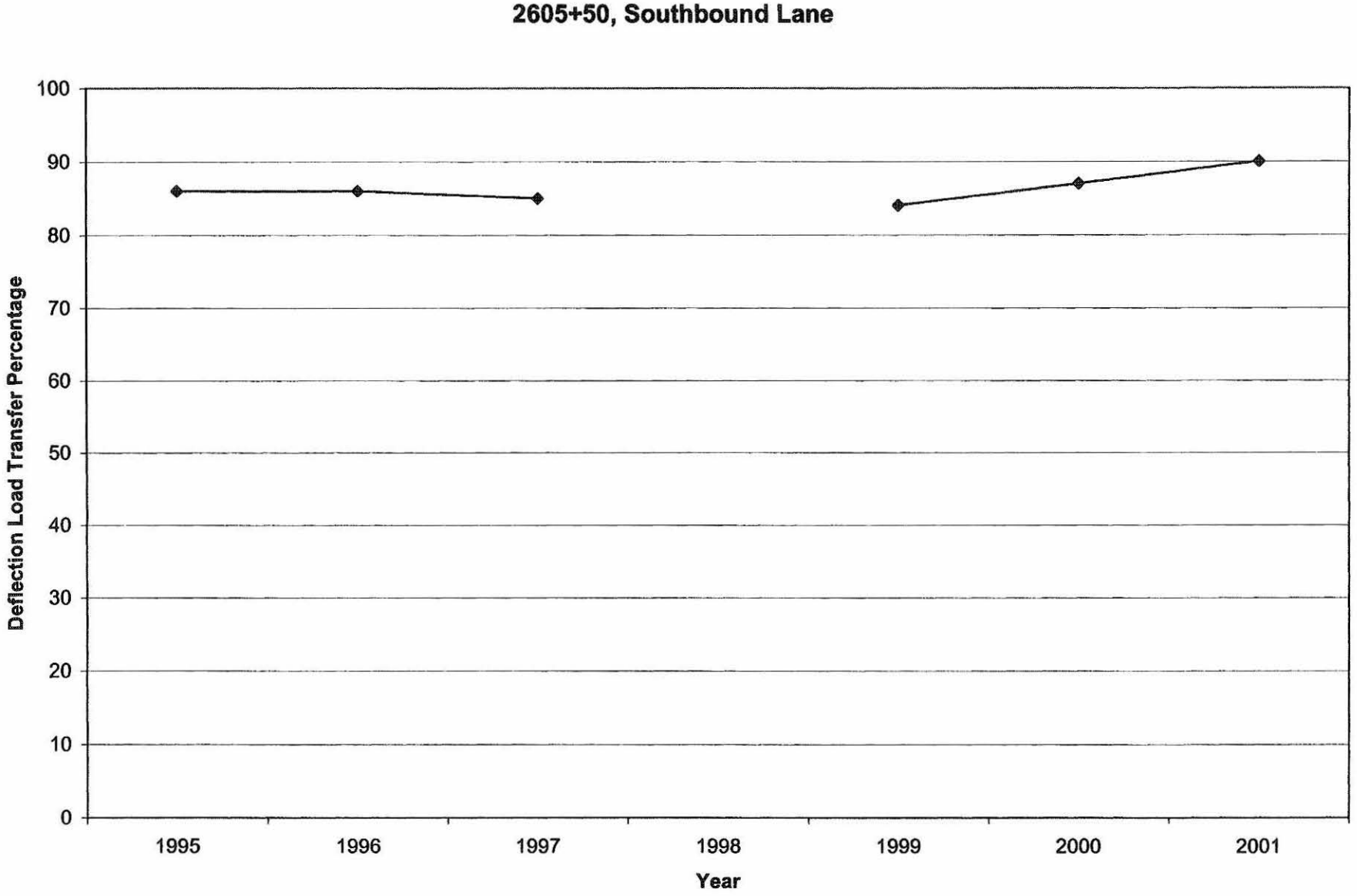
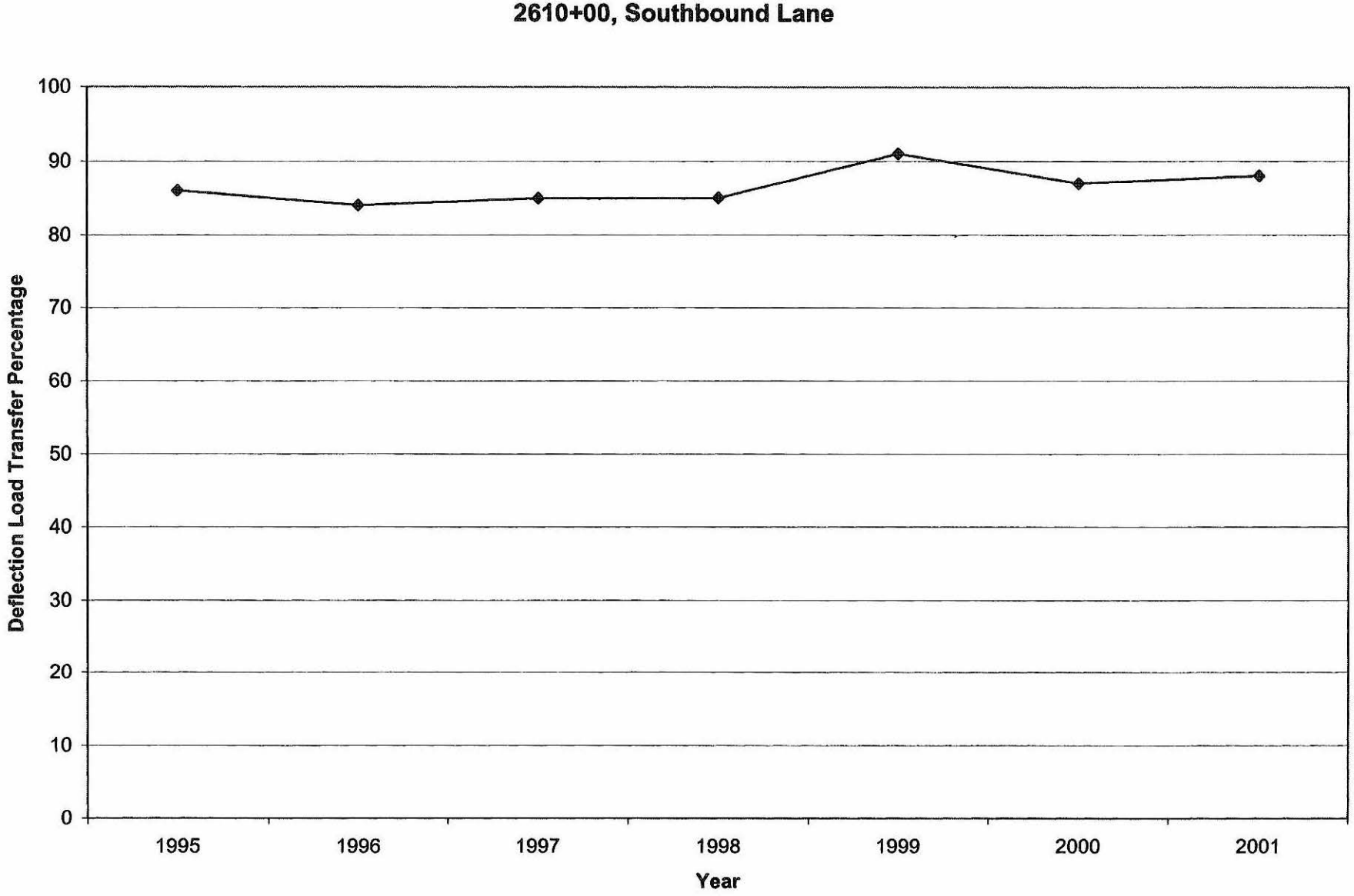
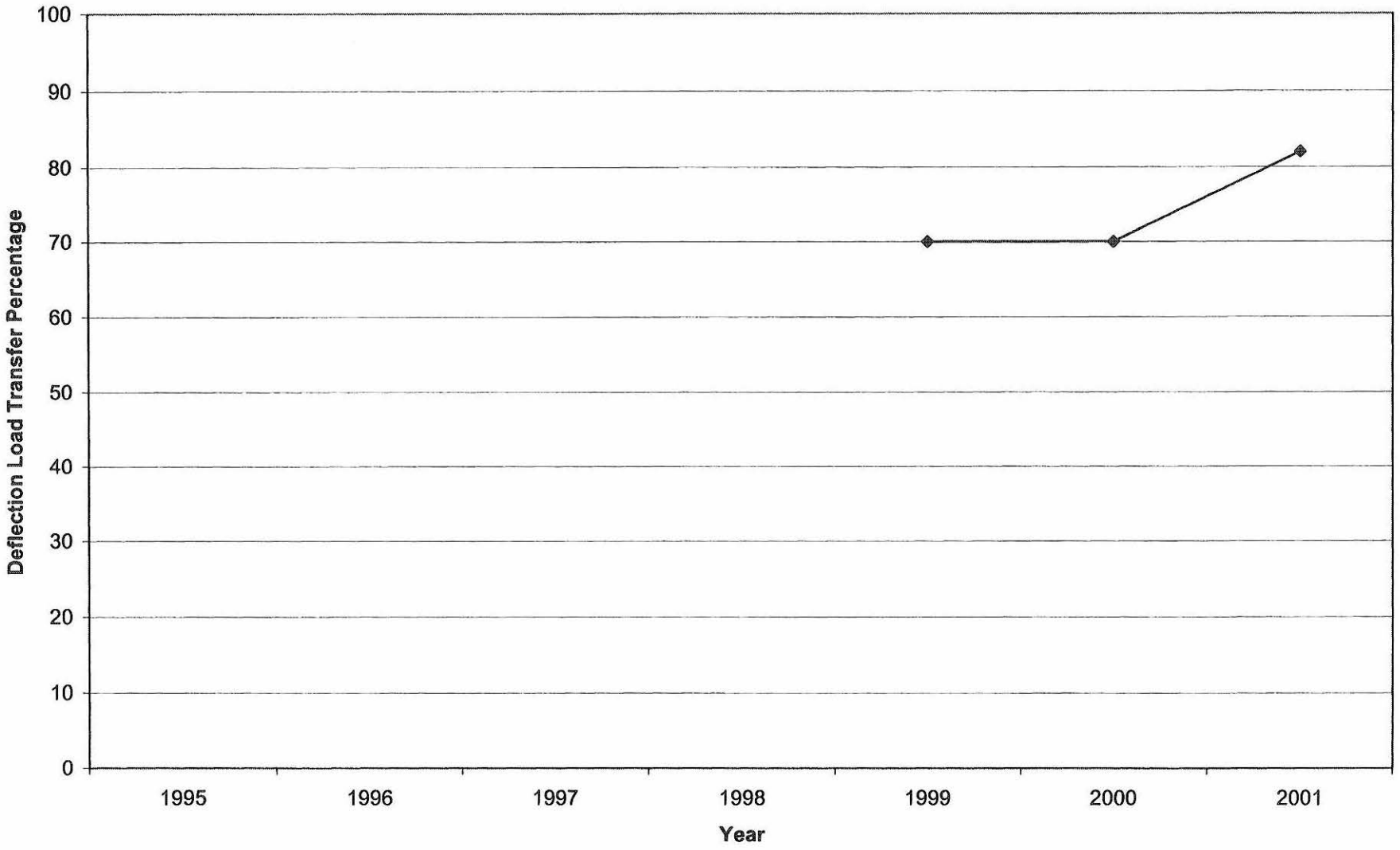
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year

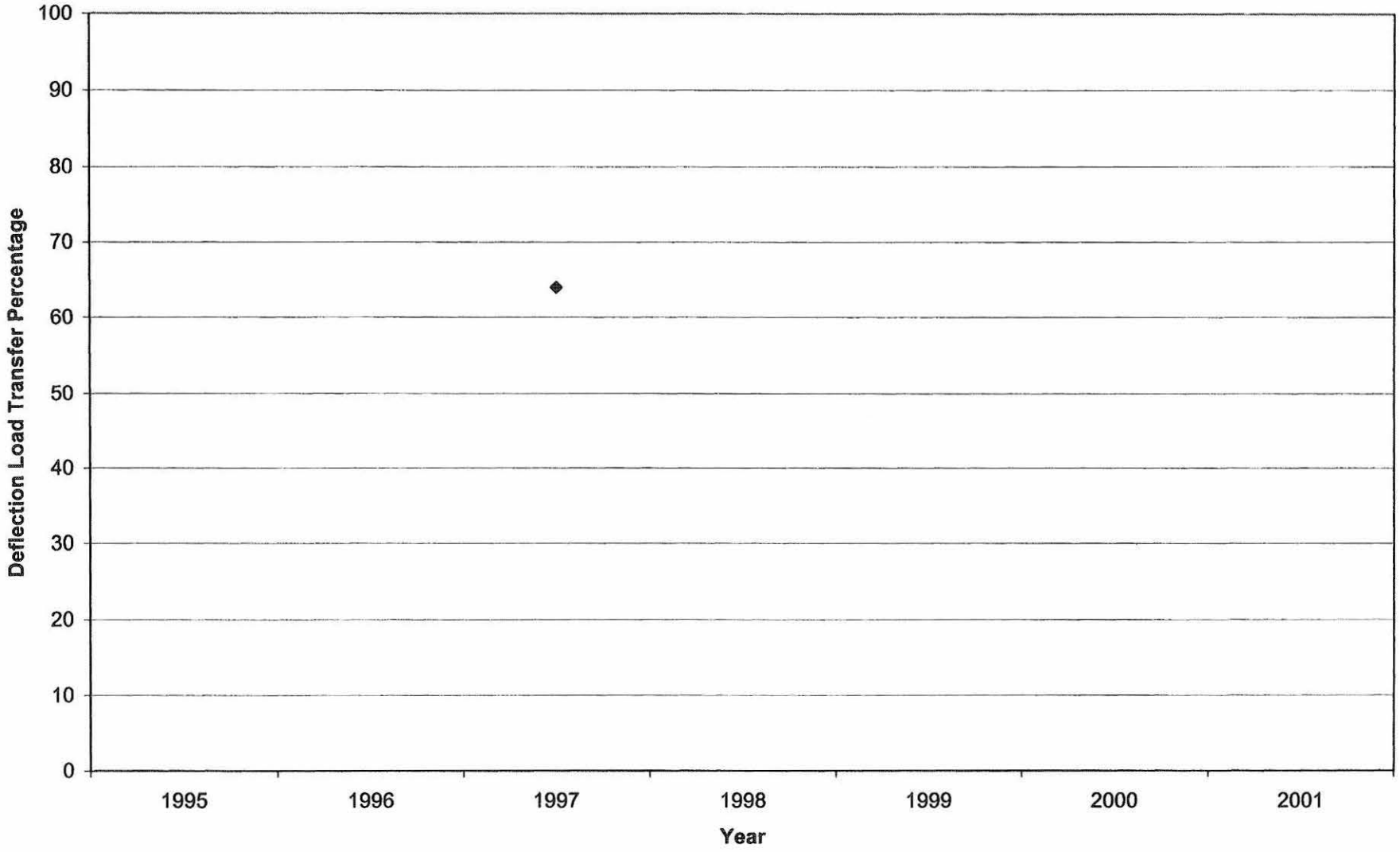

2596+00, Southbound Lane
Deflection Load Transfer Percentage
100
90
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year

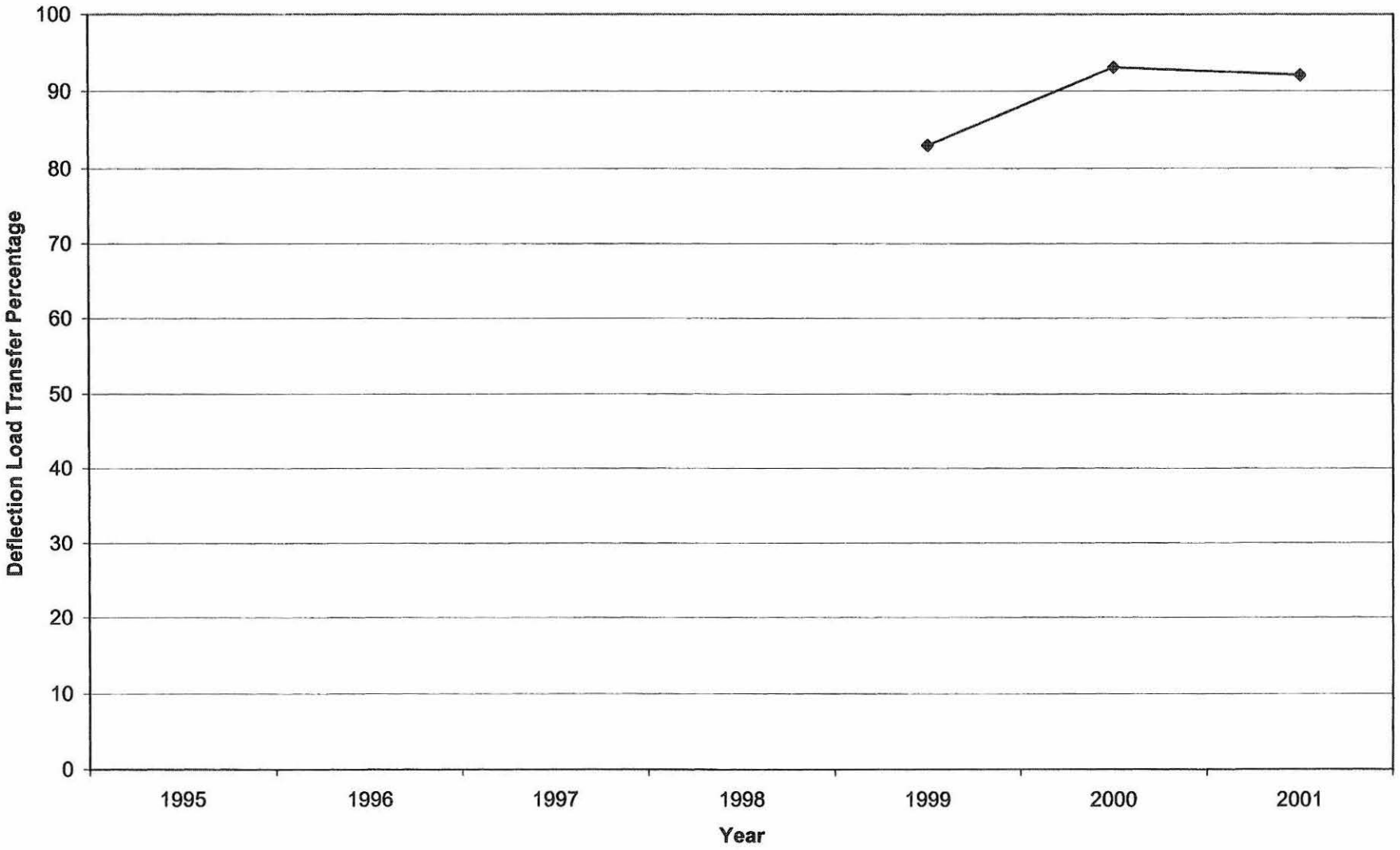

2605+50, Southbound Lane
Deflection Load Transfer Percentage
100
90
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year

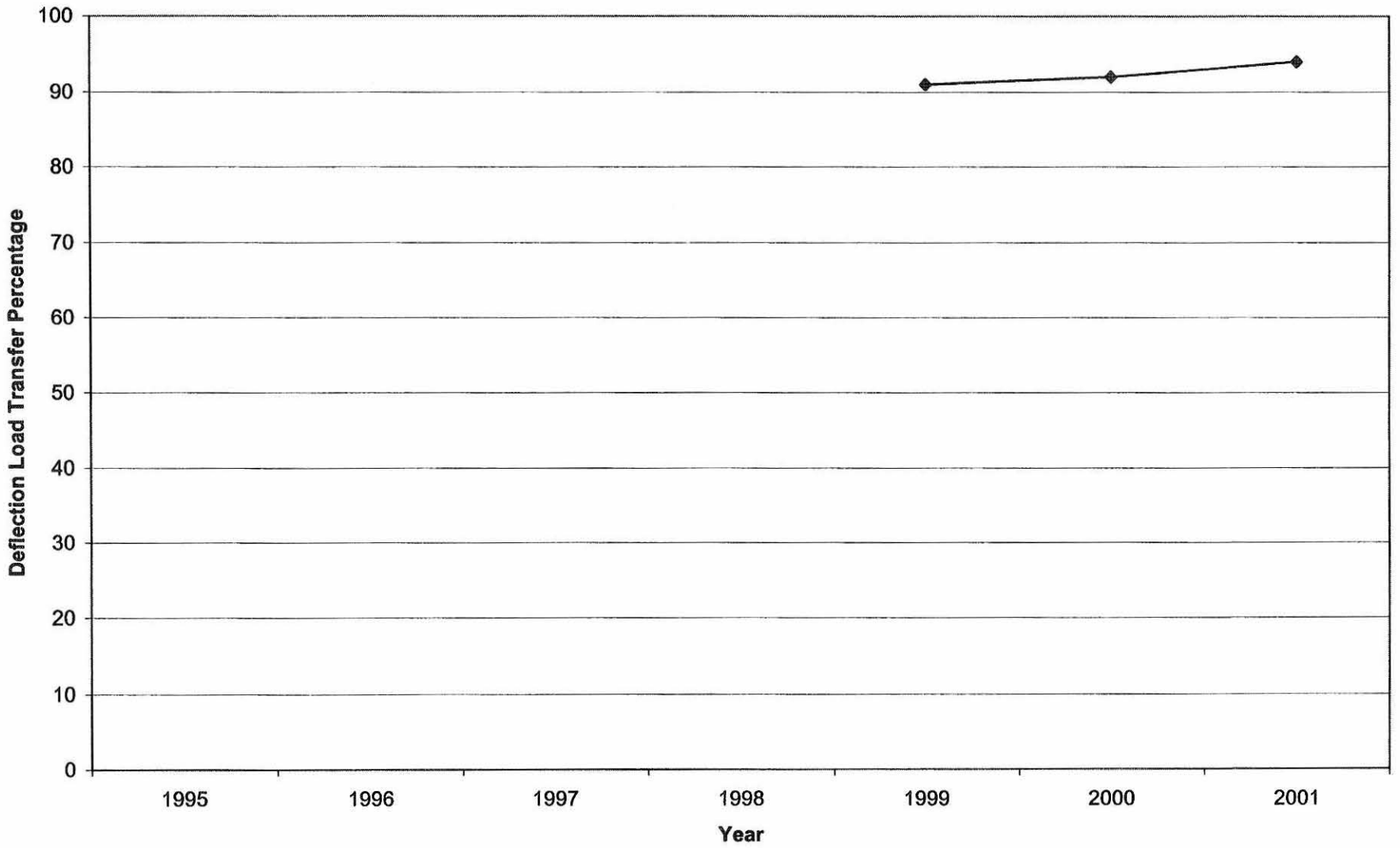

2610+00, Southbound Lane
Deflection Load Transfer Percentage
100
90
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year

2622+61, Southbound Lane



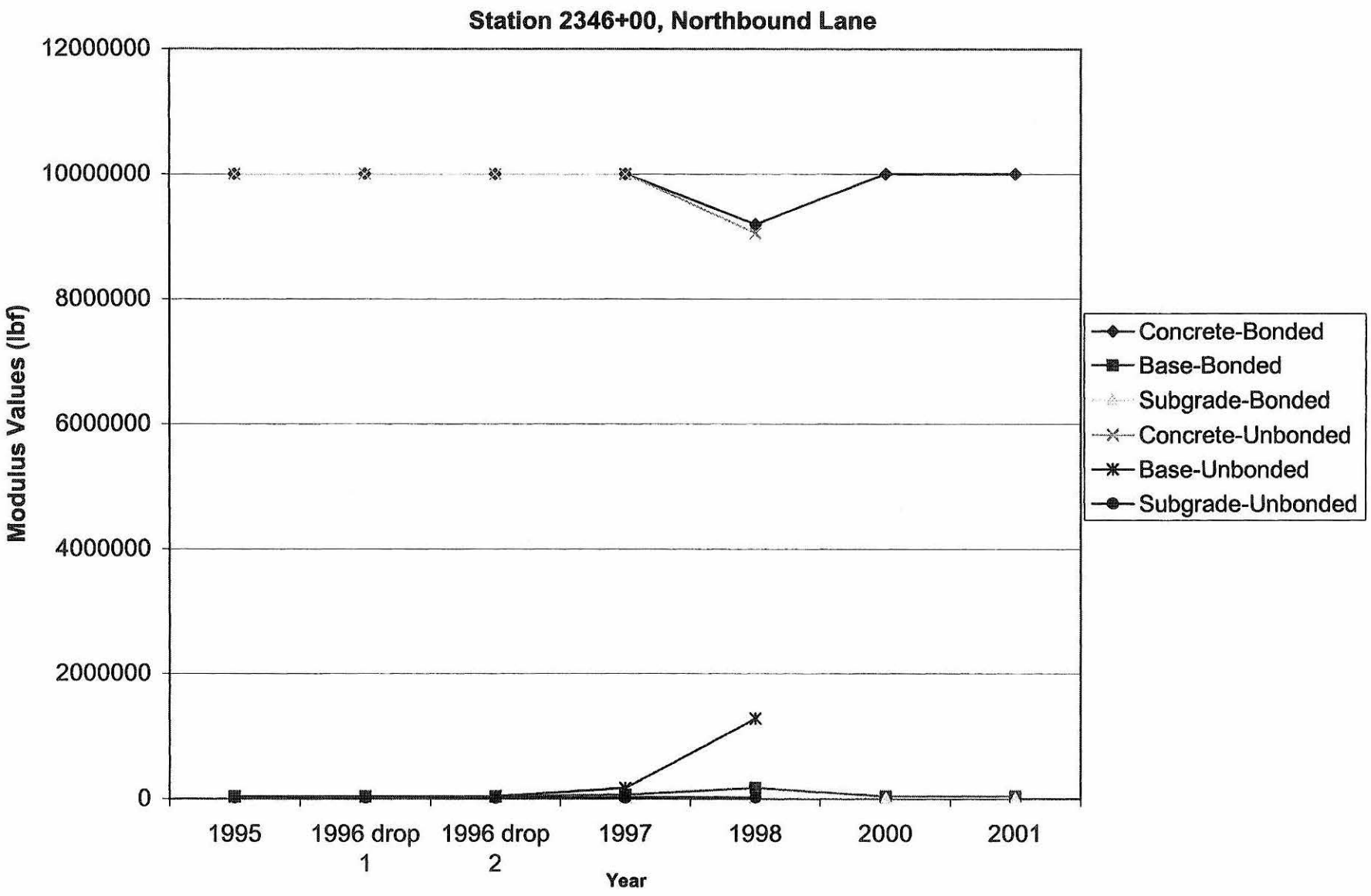

2692+60, Southbound Lane
Deflection Load Transfer Percentage
100
90
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year


2695+75, Southbound Lane
Deflection Load Transfer Percentage
100
90
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year

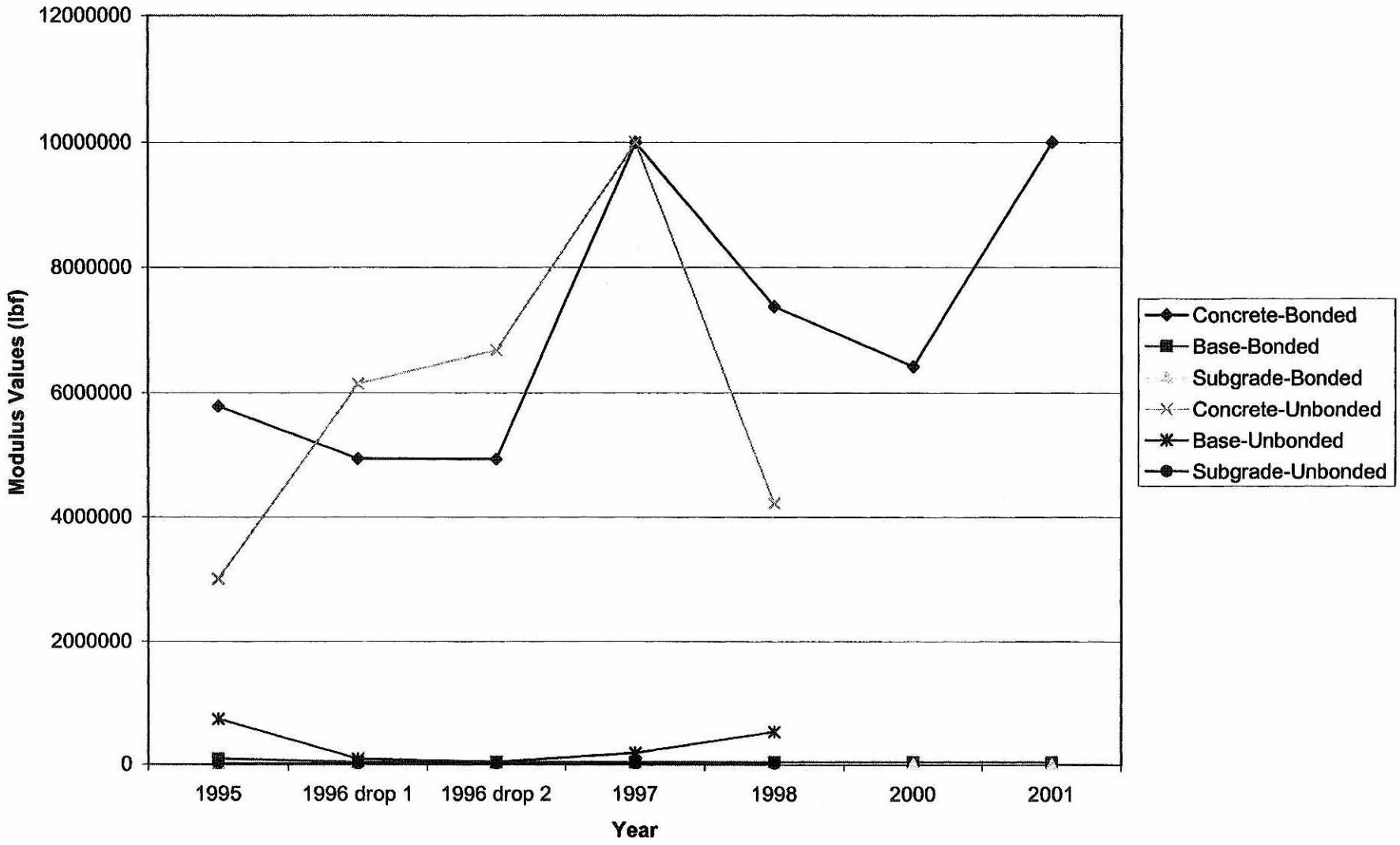

2697+25, Southbound Lane
Deflection Load Transfer Percentage
100
90
80
70
60
50
40
30
20
10
0
1995
1996
1997
1998
1999
2000
2001
Year

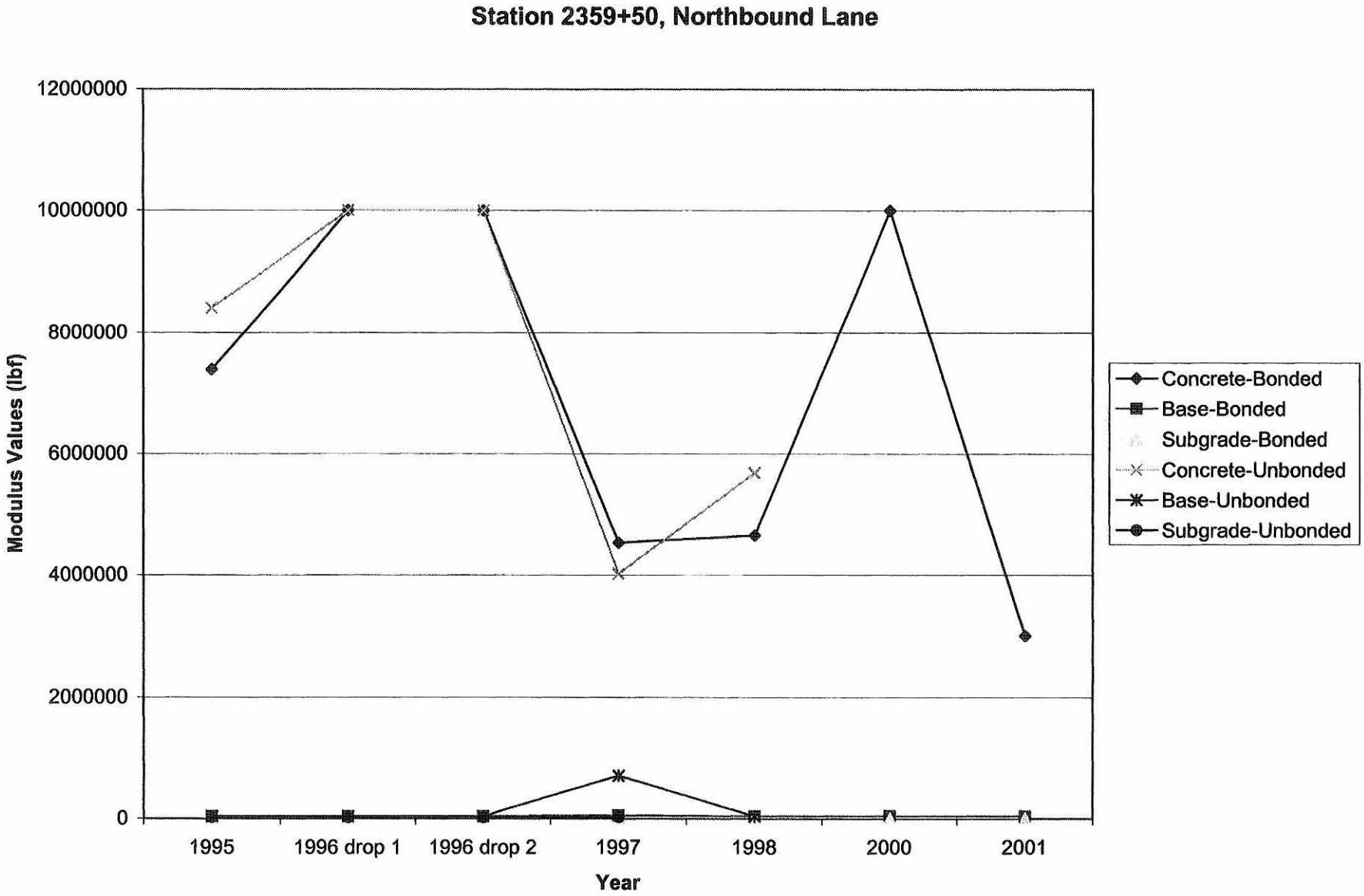
APPENDIX C

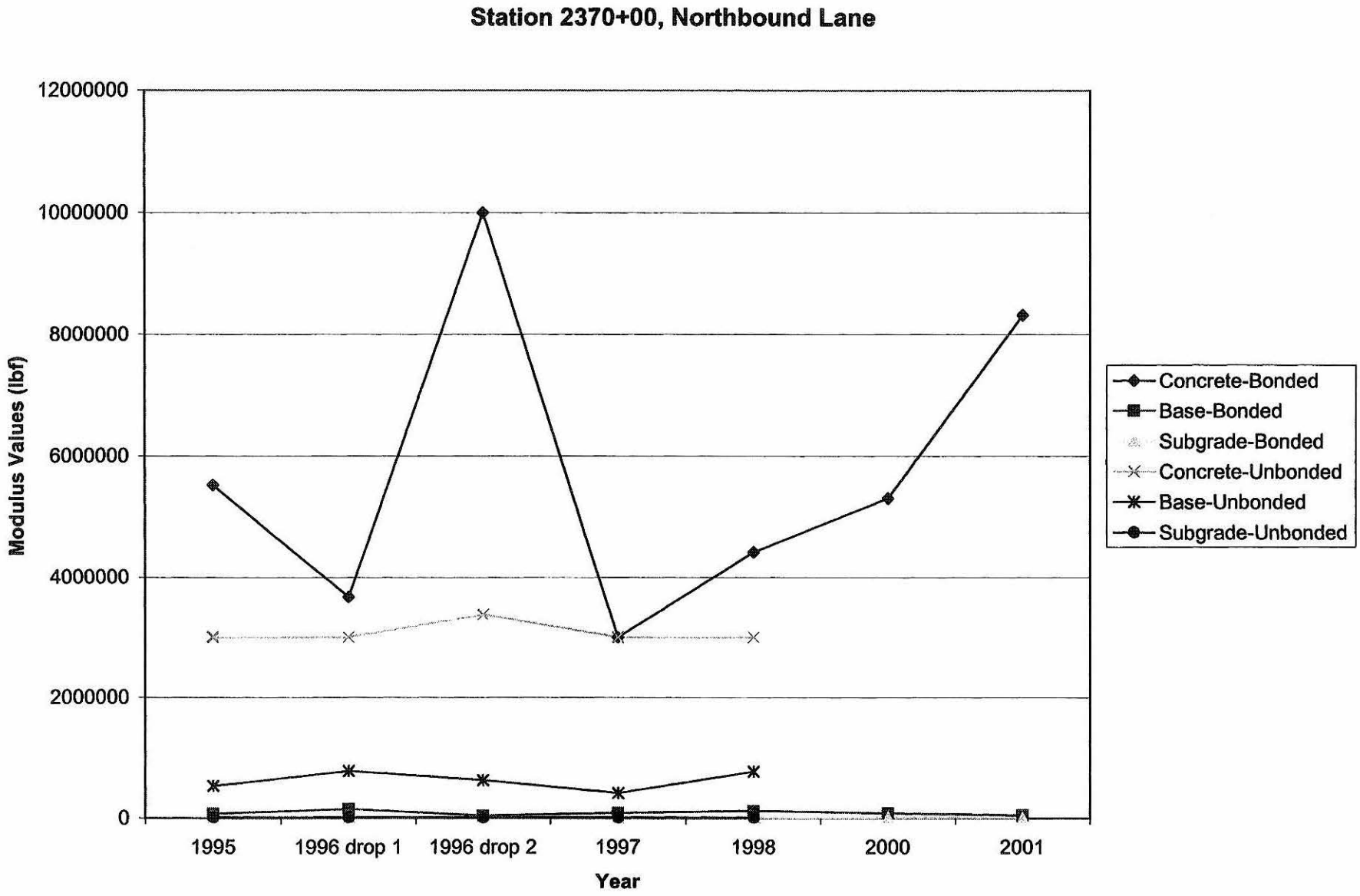
Backcalculated Modulus Values

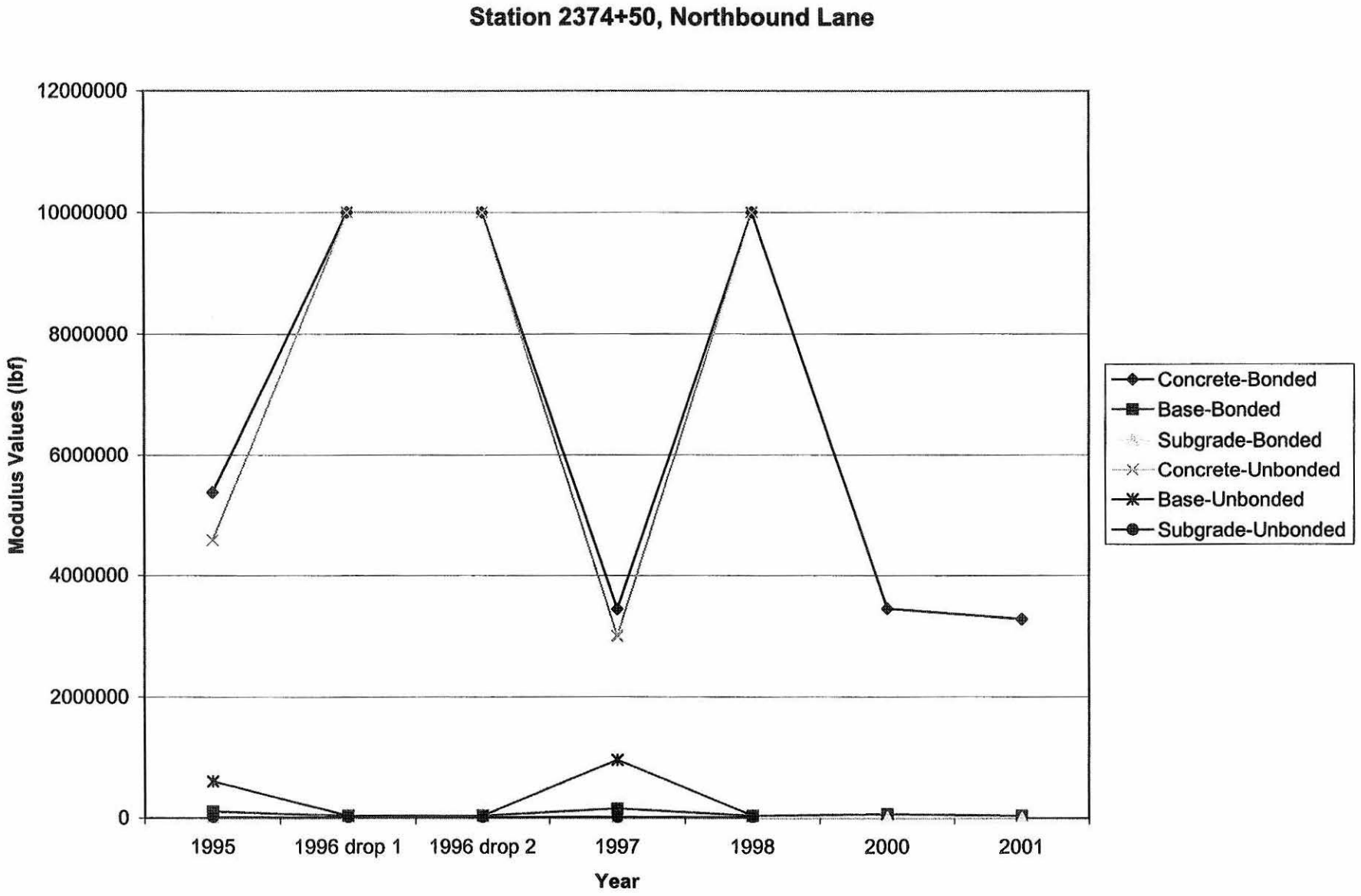

Station 2346+00, Northbound Lane
12000000
10000000
8000000
6000000
4000000
2000000
0
Modulus Values (lbf)
1995
1996 drop 1
1996 drop 2
1997
1998
2000
2001
Year
Concrete-Bonded
Base-Bonded
Subgrade-Bonded
Concrete-Unbonded
Base-Unbonded
Subgrade-Unbonded

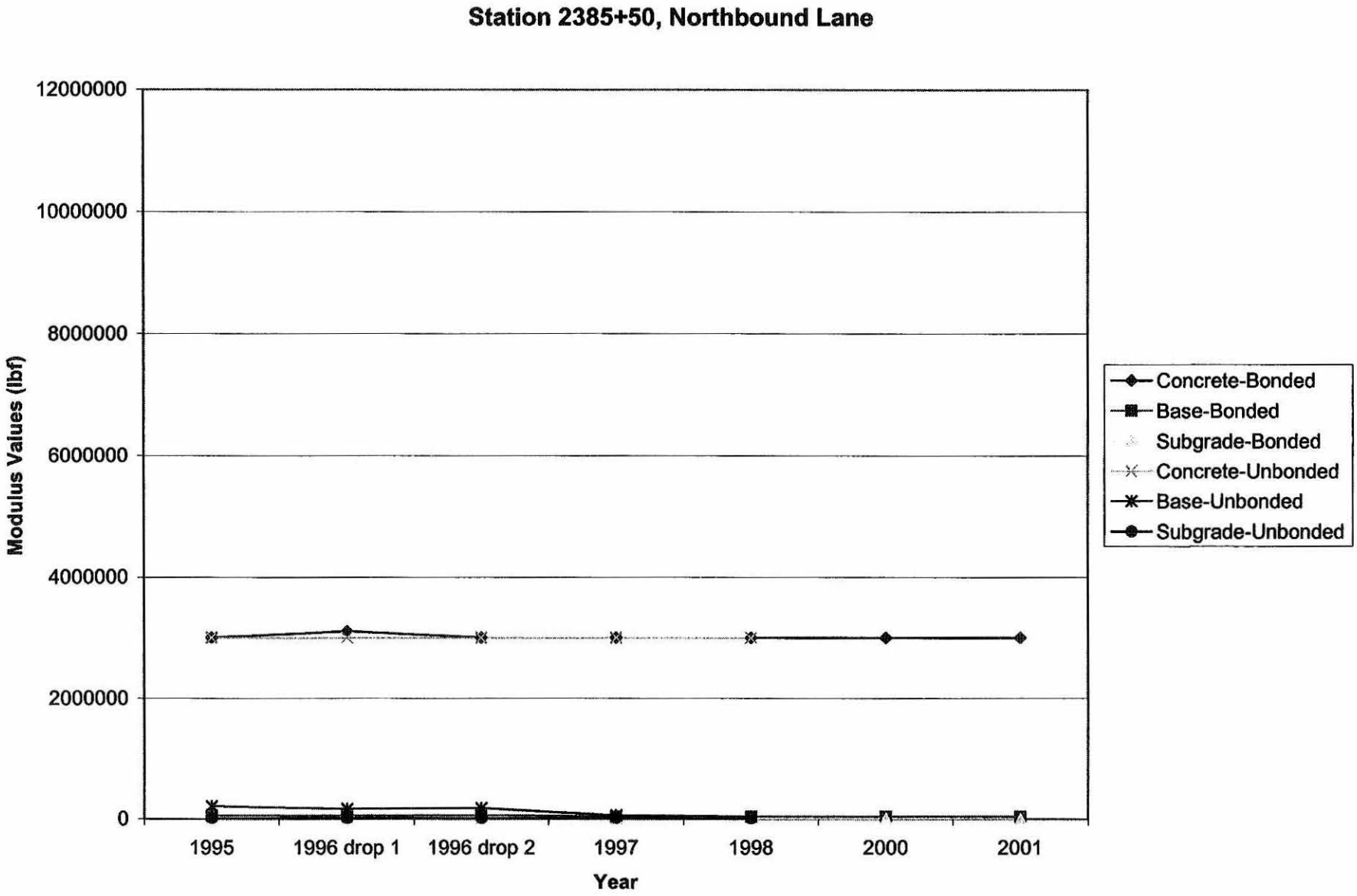
Station 2354+00, Northbound Lane

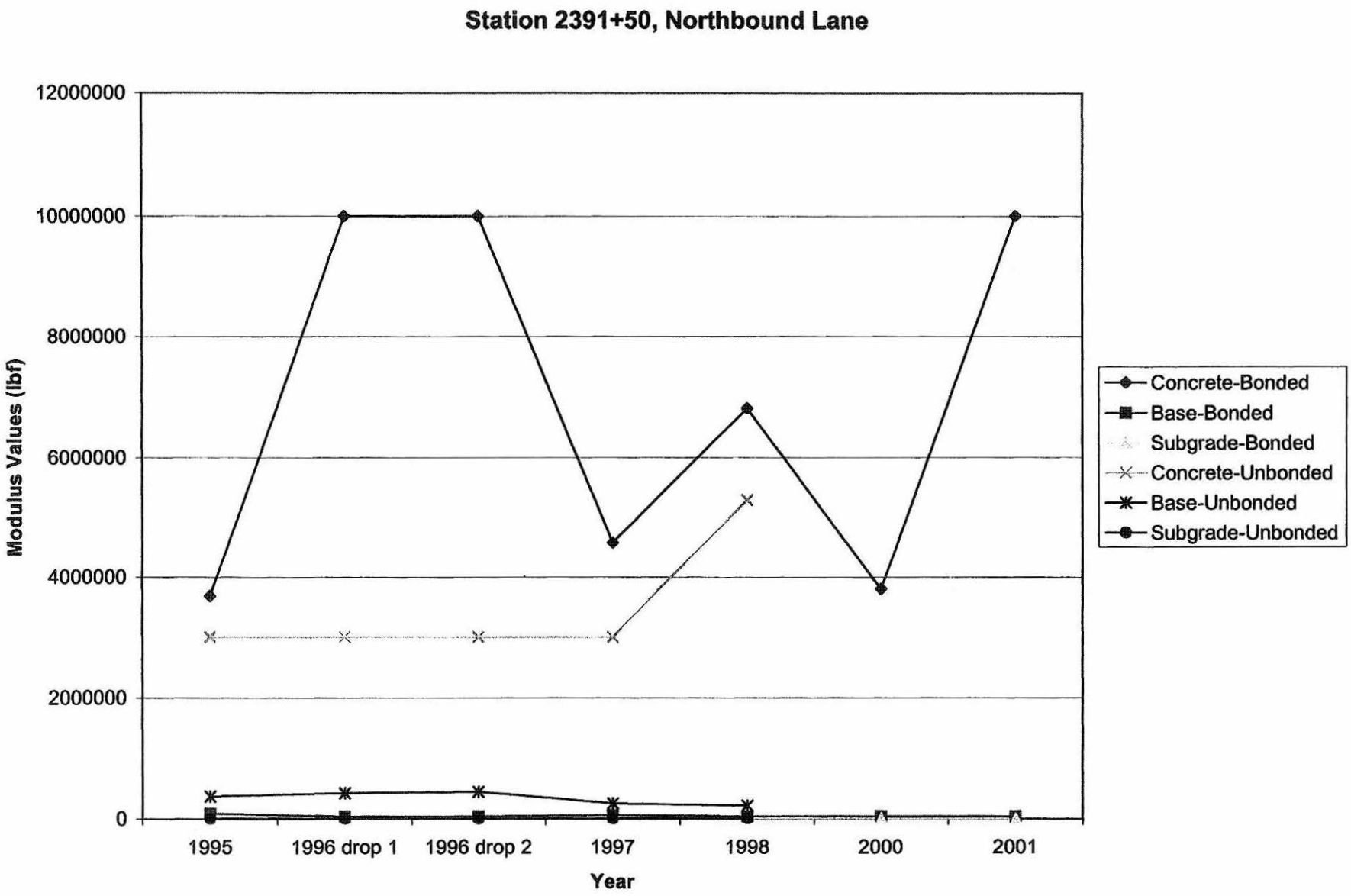


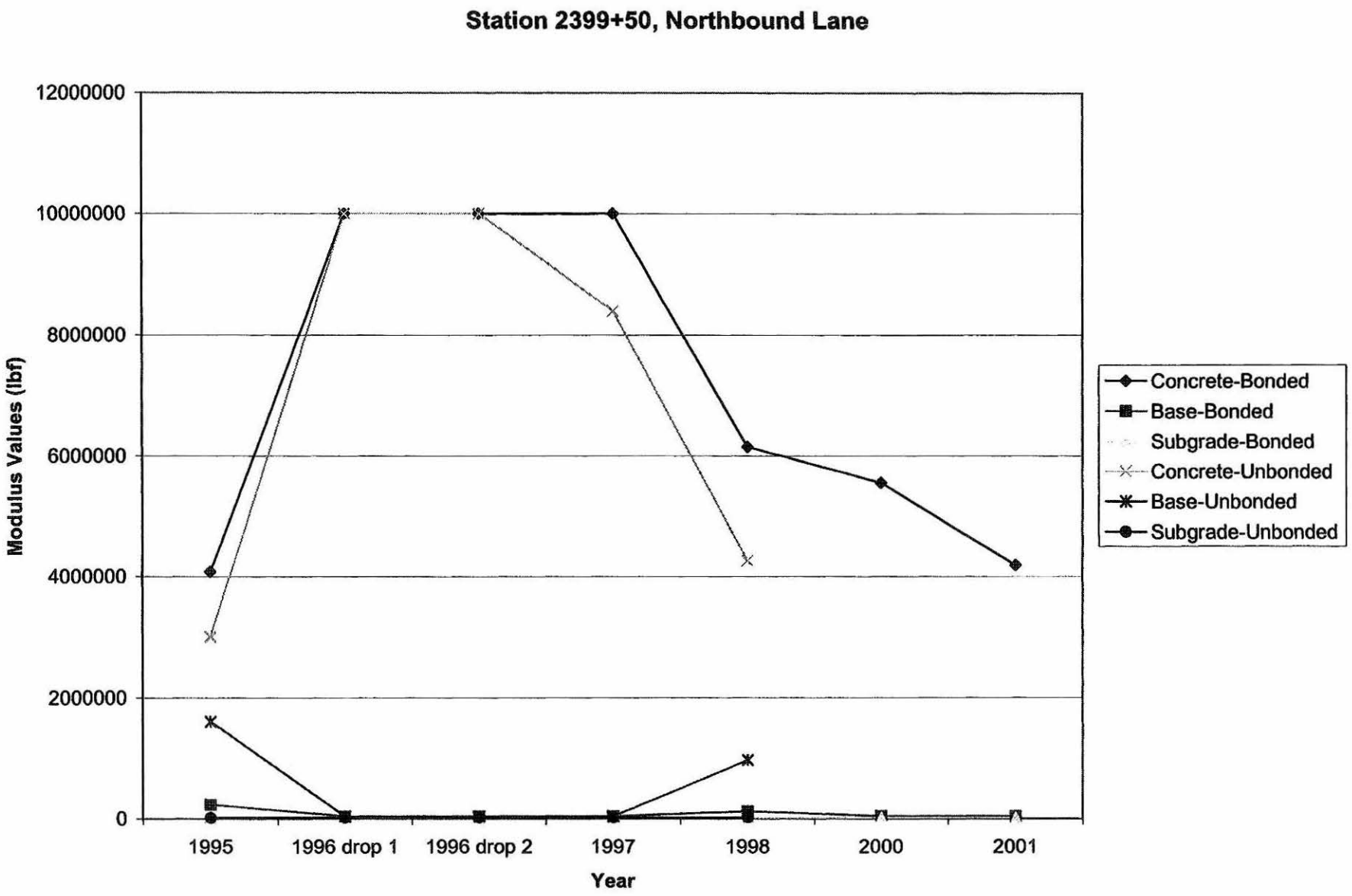

Station 2359+50, Northbound Lane
12000000
10000000
8000000
6000000
4000000
2000000
0
Modulus Values (lbf)
1995
1996 drop 1
1996 drop 2
1997
1998
2000
2001
Year
Concrete-Bonded
Base-Bonded
Subgrade-Bonded
Concrete-Unbonded
Base-Unbonded
Subgrade-Unbonded


Station 2370+00, Northbound Lane
12000000
10000000
8000000
6000000
4000000
2000000
0
Modulus Values (lbf)
1995
1996 drop 1
1996 drop 2
1997
1998
2000
2001
Year
Concrete-Bonded
Base-Bonded
Subgrade-Bonded
Concrete-Unbonded
Base-Unbonded
Subgrade-Unbonded

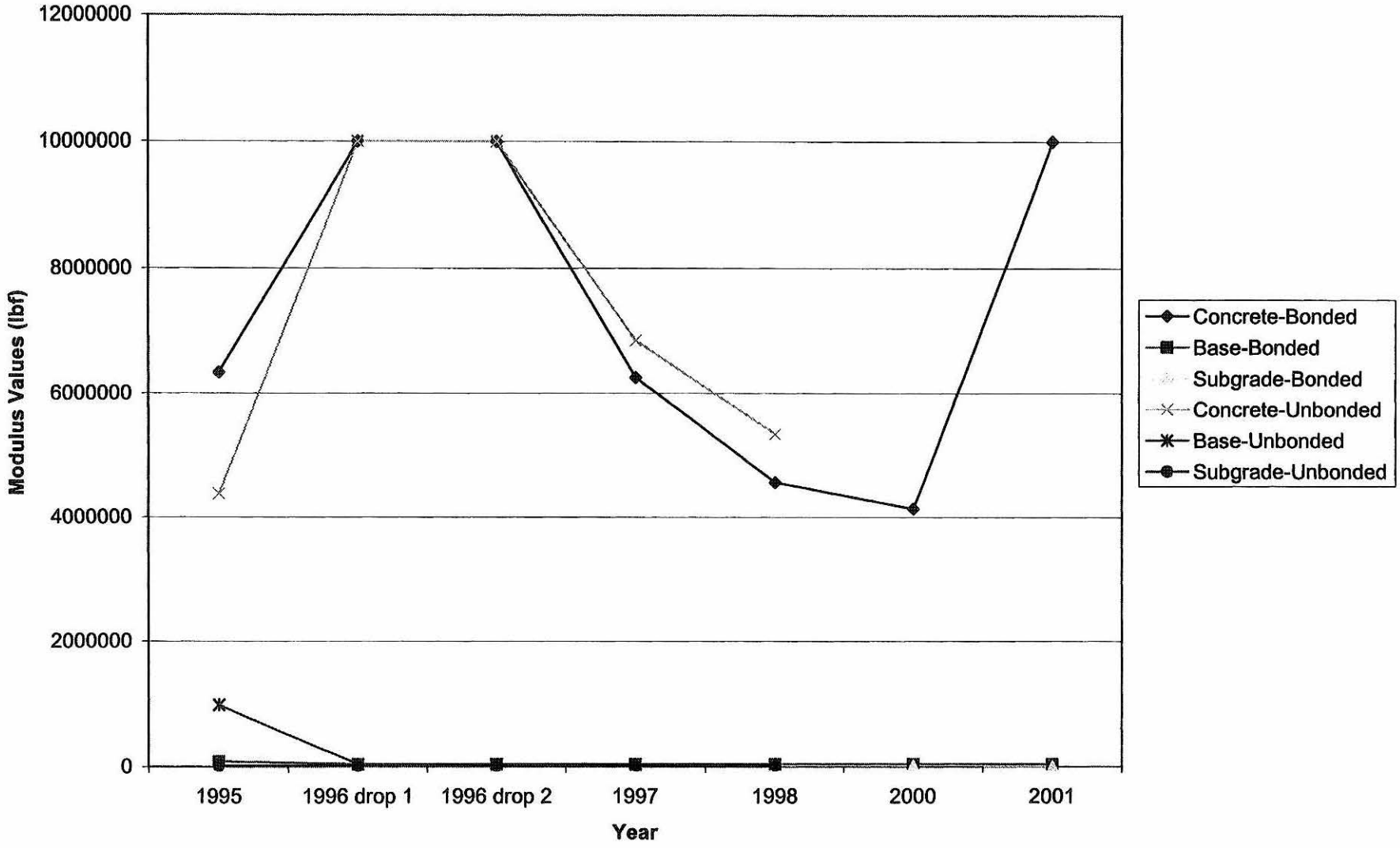

Station 2374+50, Northbound Lane
12000000
10000000
8000000
6000000
4000000
2000000
0
Modulus Values (lbf)
1995
1996 drop 1
1996 drop 2
1997
1998
2000
2001
Year
Concrete-Bonded
Base-Bonded
Subgrade-Bonded
Concrete-Unbonded
Base-Unbonded
Subgrade-Unbonded


Station 2385+50, Northbound Lane
12000000
10000000
8000000
6000000
4000000
2000000
0
Modulus Values (lbf)
1995
1996 drop 1
1996 drop 2
1997
1998
2000
2001
Year
Concrete-Bonded
Base-Bonded
Subgrade-Bonded
Concrete-Unbonded
Base-Unbonded
Subgrade-Unbonded

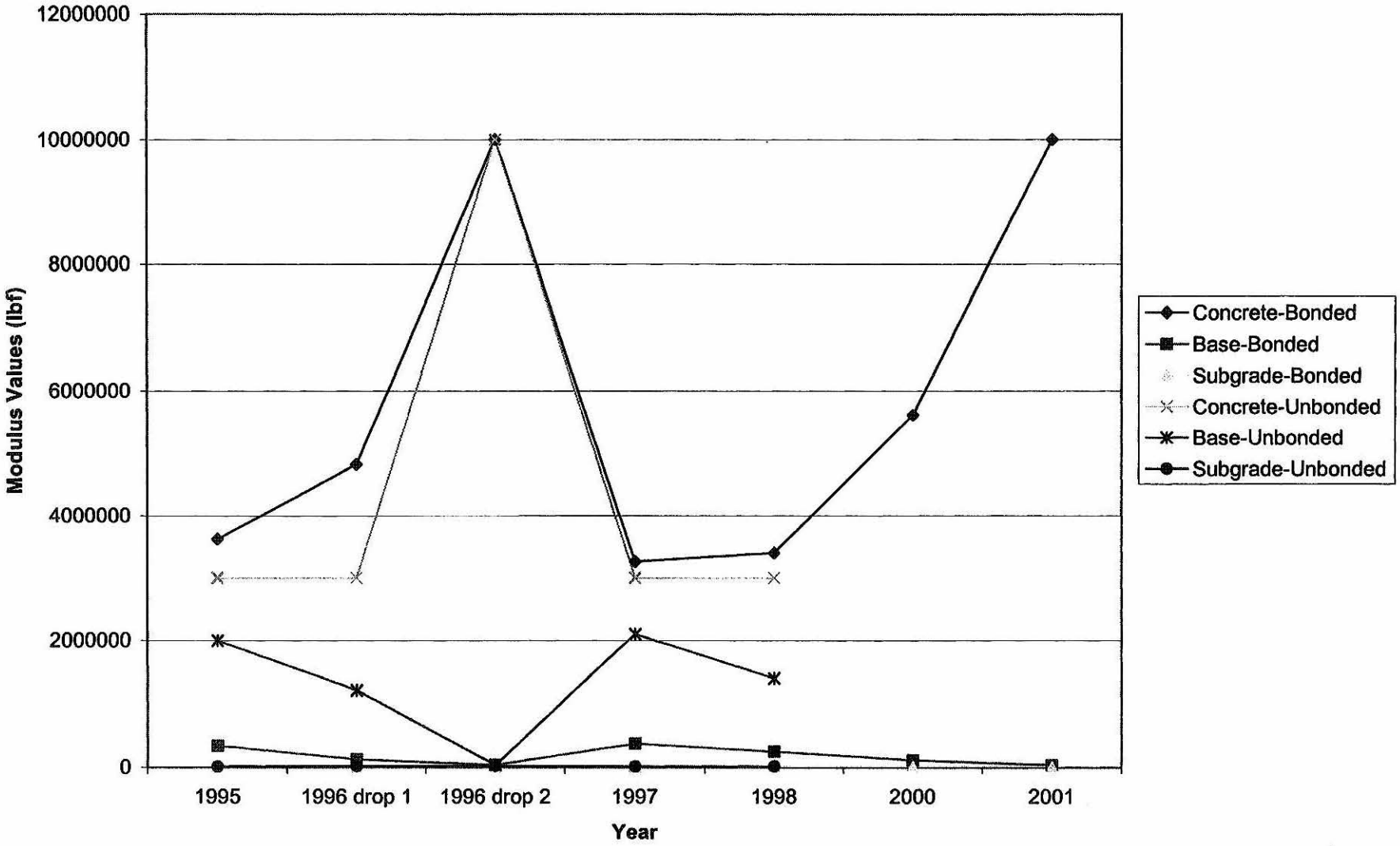

Station 2391+50, Northbound Lane
12000000
10000000
8000000
6000000
4000000
2000000
0
Modulus Values (lbf)
1995
1996 drop 1
1996 drop 2
1997
1998
2000
2001
Year
Concrete-Bonded
Base-Bonded
Subgrade-Bonded
Concrete-Unbonded
Base-Unbonded
Subgrade-Unbonded


Station 2399+50, Northbound Lane
12000000
10000000
8000000
6000000
4000000
2000000
0
Modulus Values (lbf)
1995
1996 drop 1
1996 drop 2
1997
1998
2000
2001
Year
Concrete-Bonded
Base-Bonded
Subgrade-Bonded
Concrete-Unbonded
Base-Unbonded
Subgrade-Unbonded

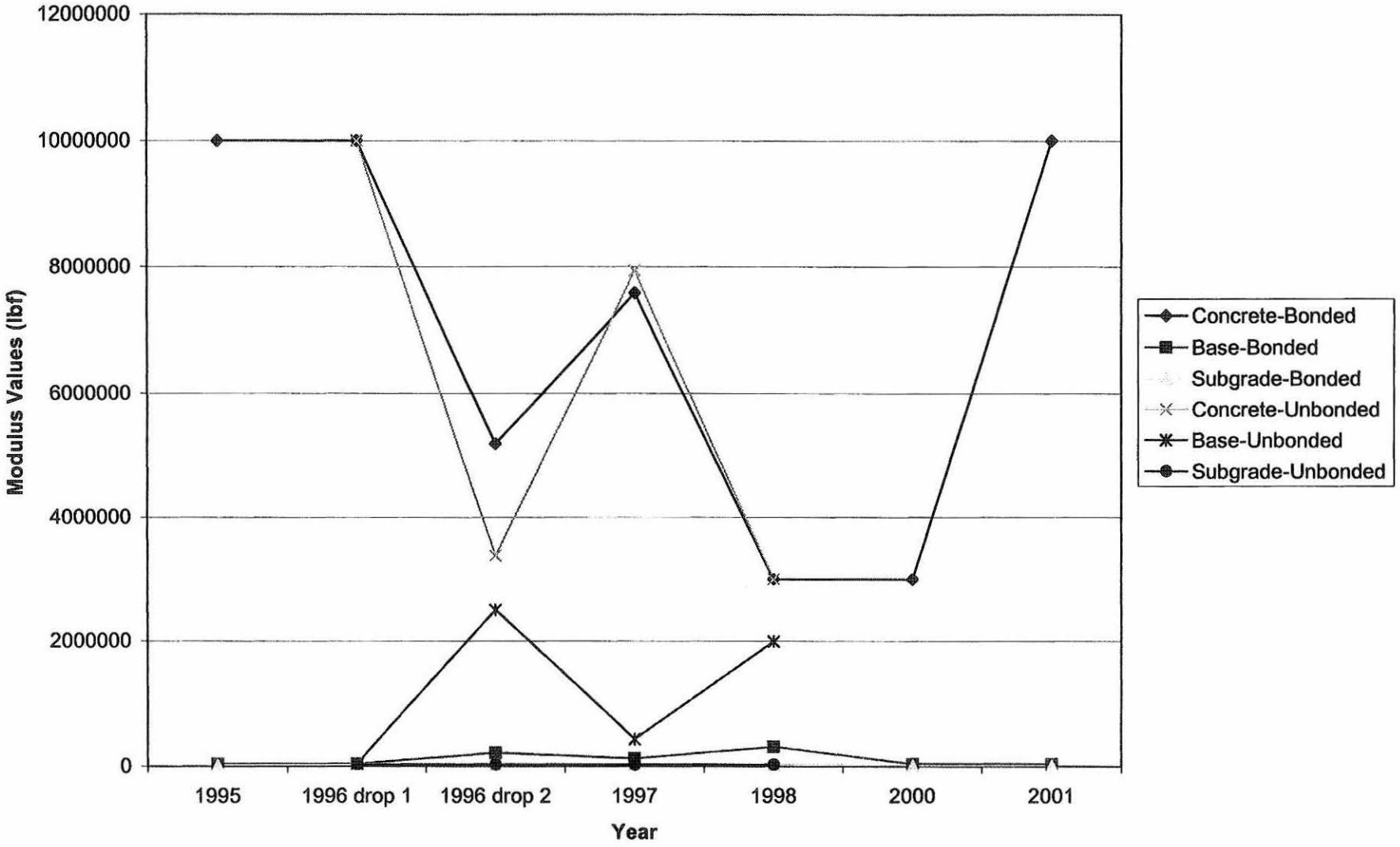
Station 2409+50, Northbound Lane

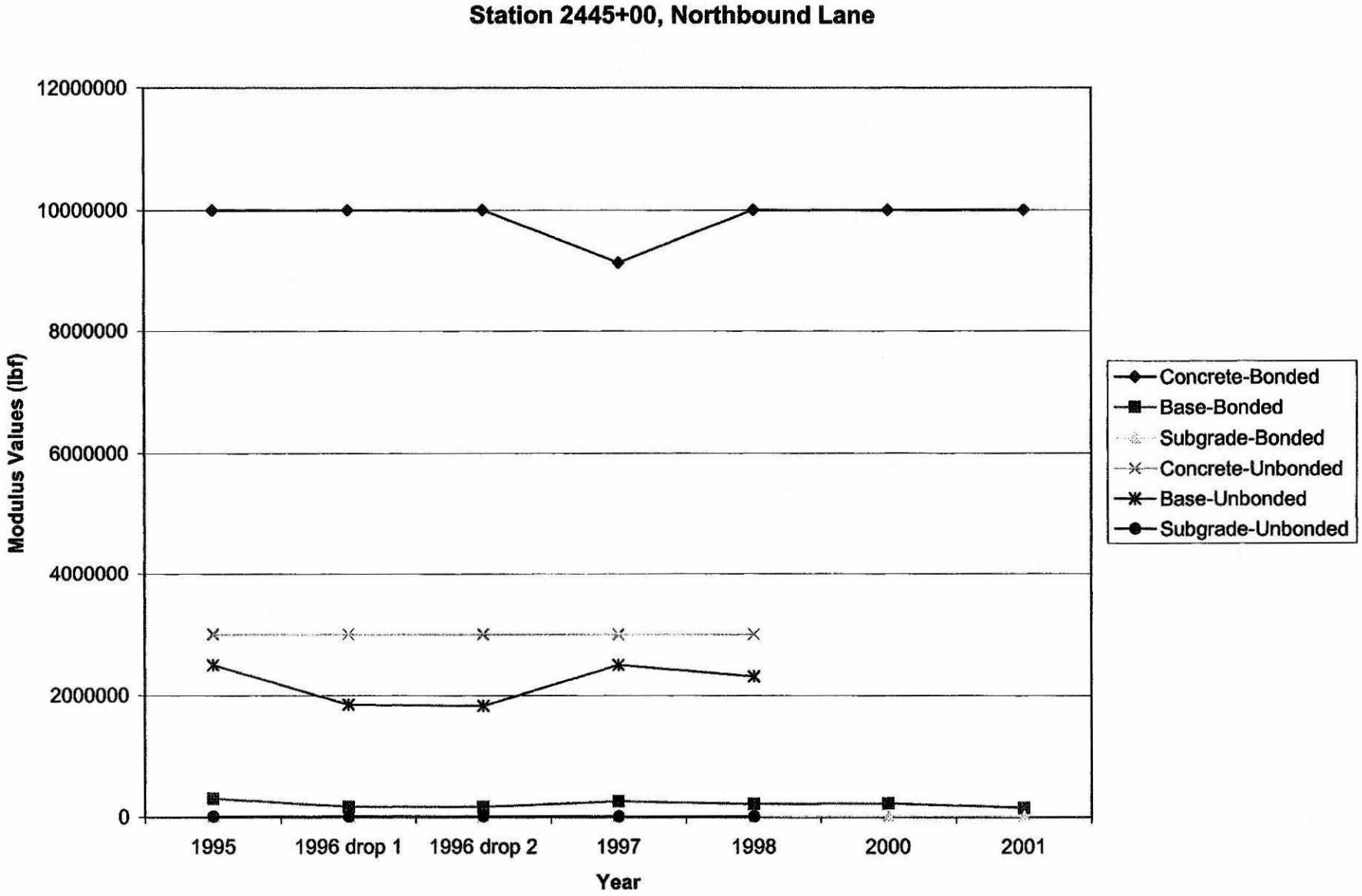


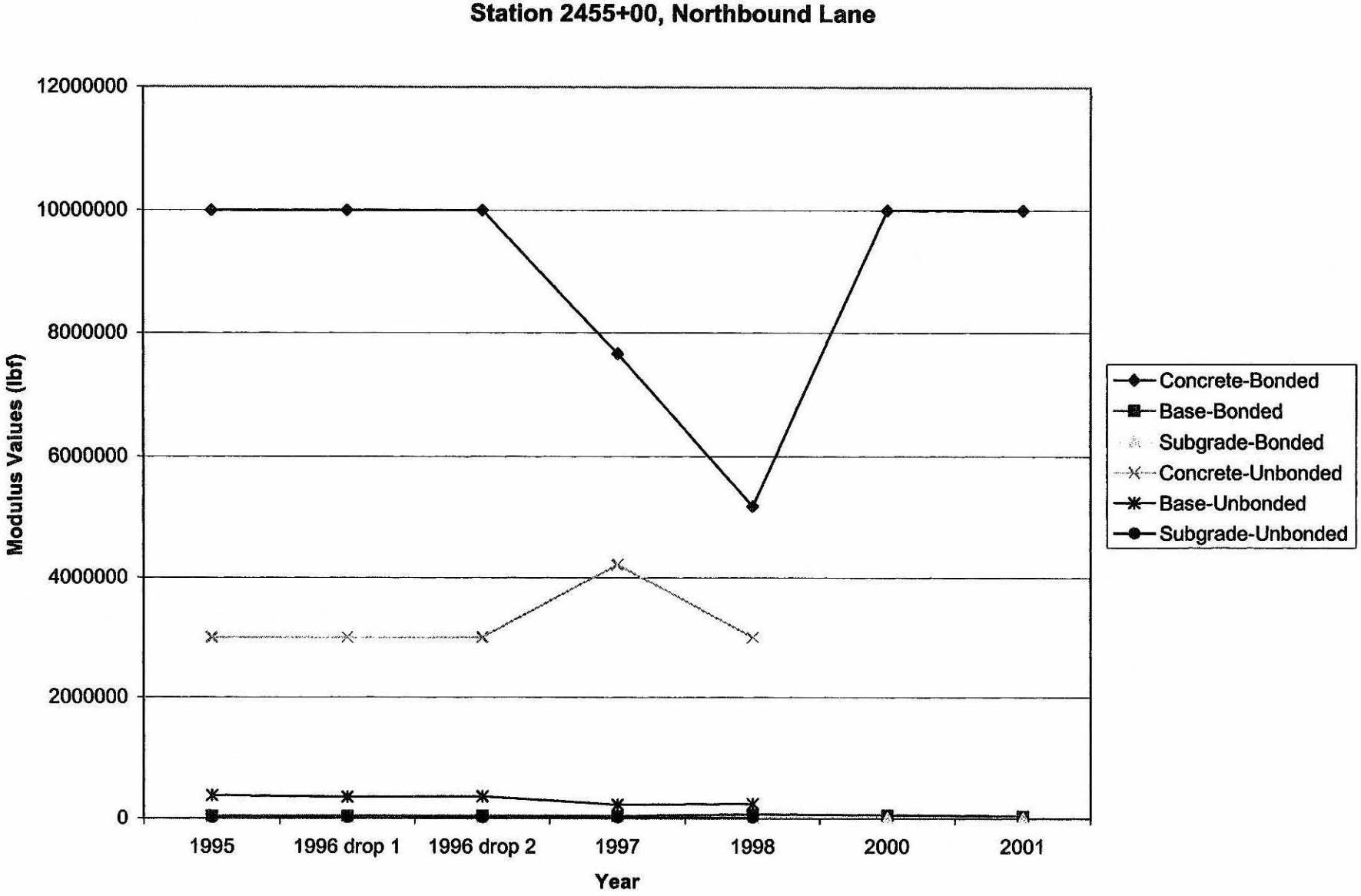
Station 2428+25, Northbound Lane



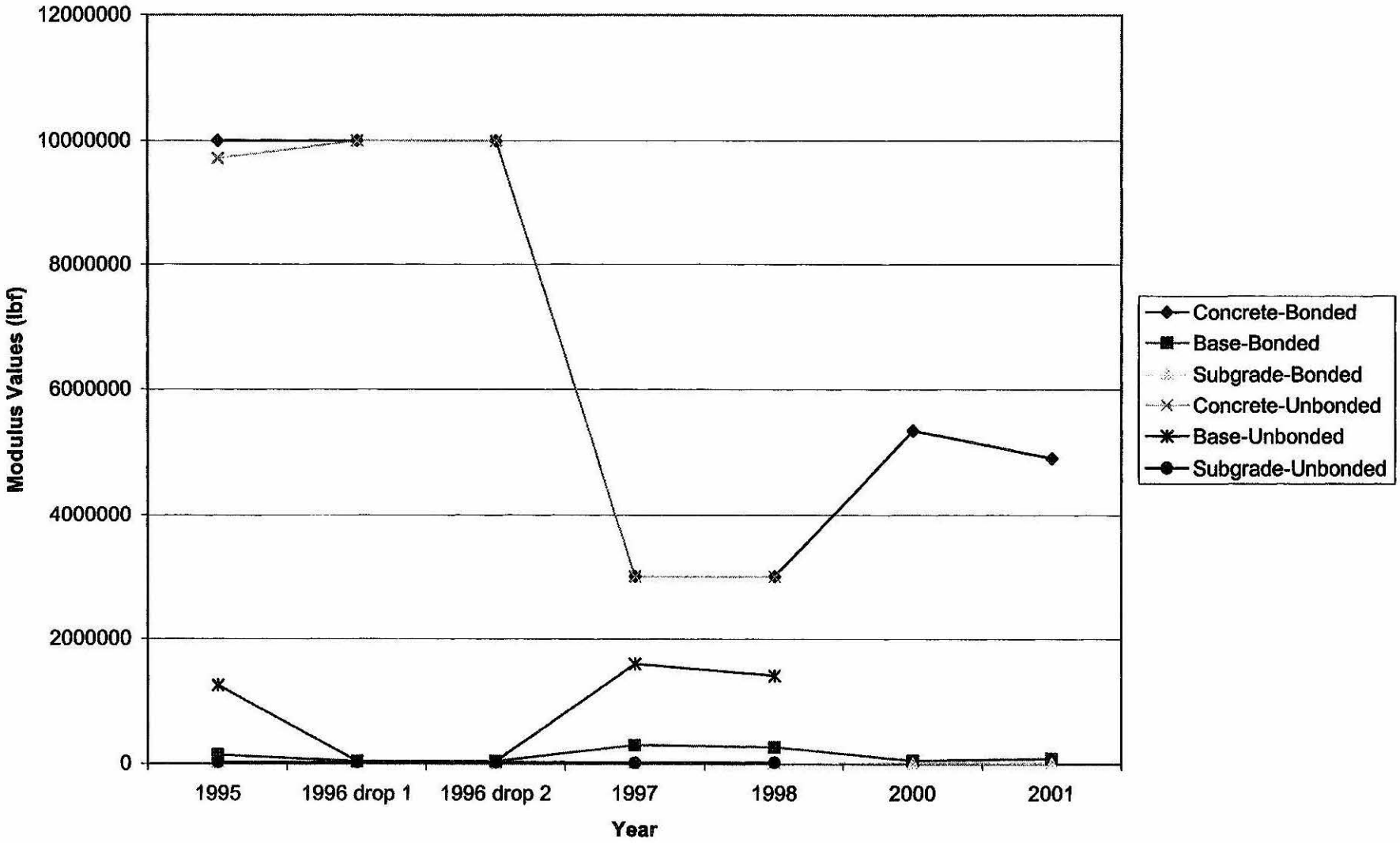
Station 2436+50, Northbound Lane

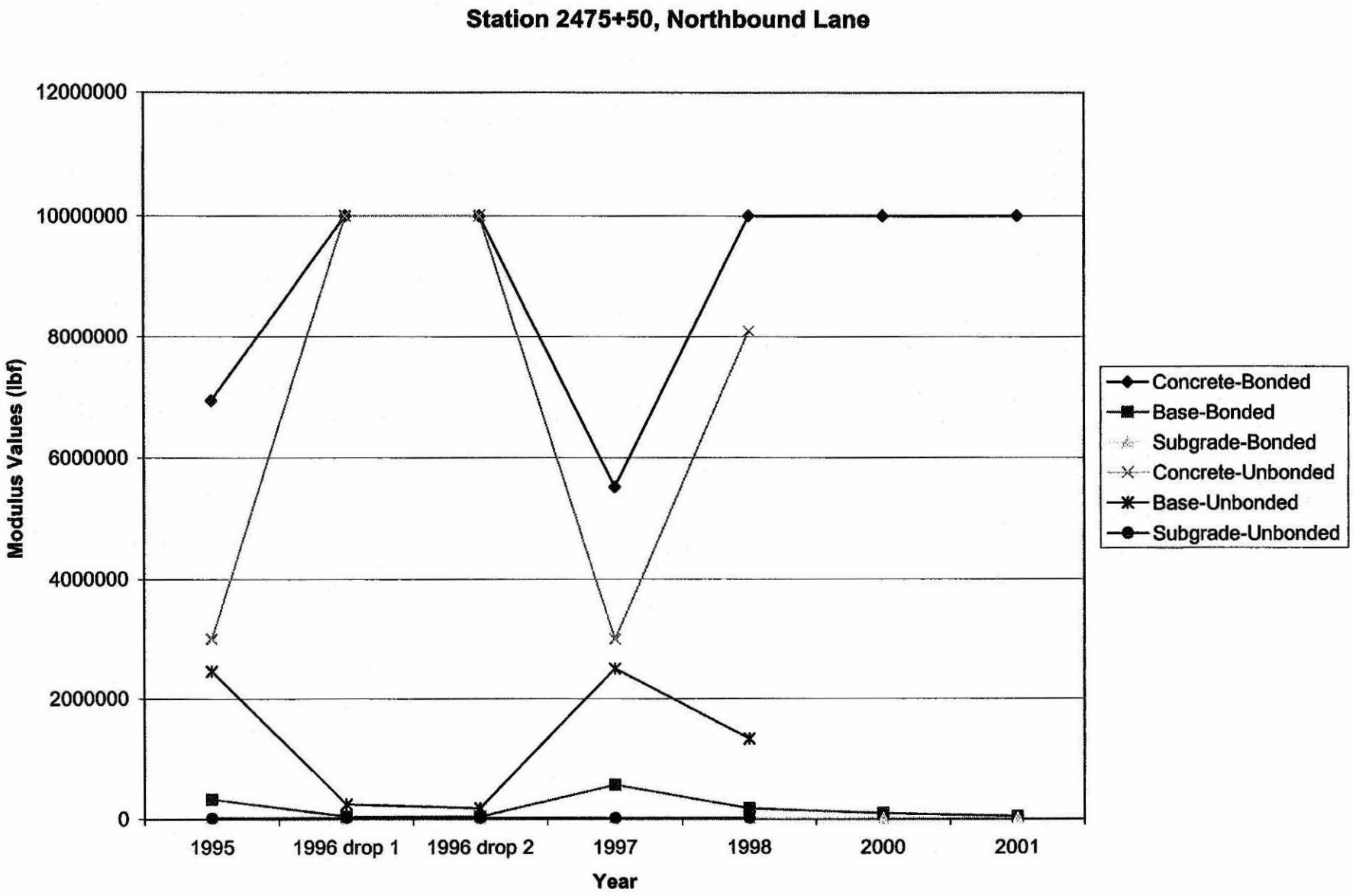



Station 2445+00, Northbound Lane
12000000
10000000
8000000
6000000
4000000
2000000
0
Modulus Values (lbf)
1995
1996 drop 1
1996 drop 2
1997
1998
2000
2001
Year
Concrete-Bonded
Base-Bonded
Subgrade-Bonded
Concrete-Unbonded
Base-Unbonded
Subgrade-Unbonded

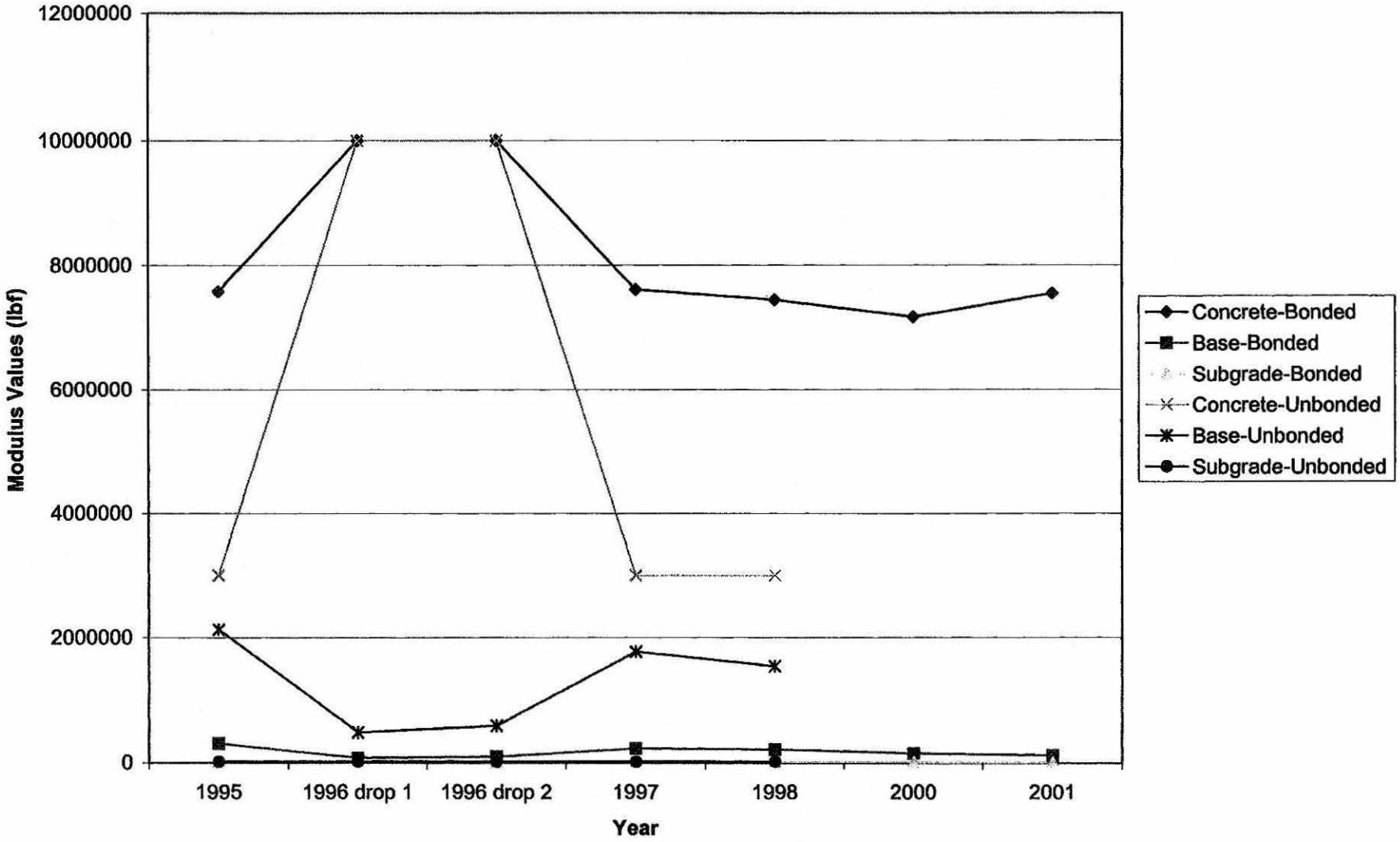

Station 2455+00, Northbound Lane
12000000
10000000
8000000
6000000
4000000
2000000
0
Modulus Values (lbf)
1995
1996 drop 1
1996 drop 2
1997
1998
2000
2001
Year
Concrete-Bonded
Base-Bonded
Subgrade-Bonded
Concrete-Unbonded
Base-Unbonded
Subgrade-Unbonded

Station 2465+00, Northbound Lane

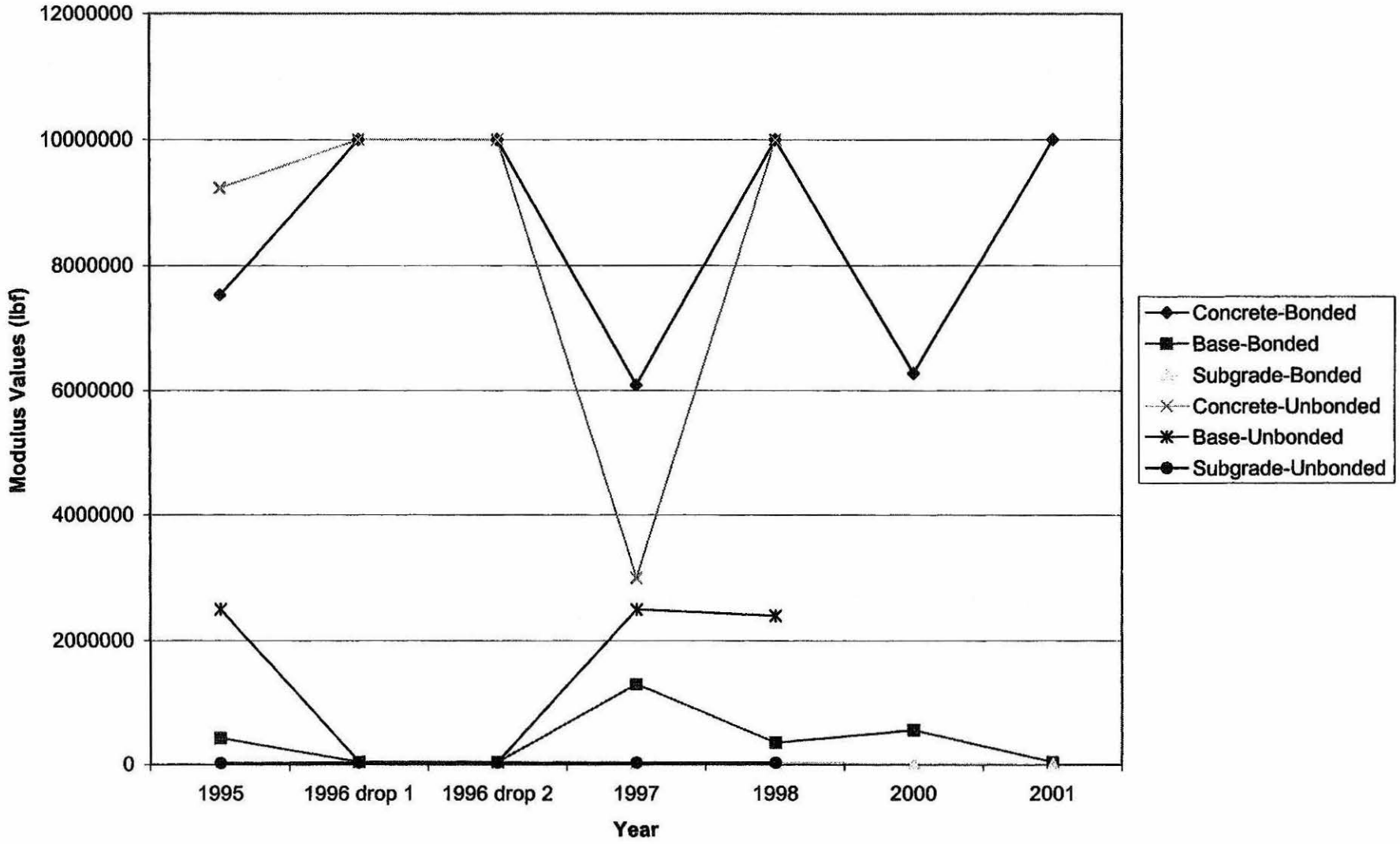



Station 2475+50, Northbound Lane
12000000
10000000
8000000
6000000
4000000
2000000
0
Modulus Values (lbf)
1995
1996 drop 1
1996 drop 2
1997
1998
2000
2001
Year
Concrete-Bonded
Base-Bonded
Subgrade-Bonded
Concrete-Unbonded
Base-Unbonded
Subgrade-Unbonded

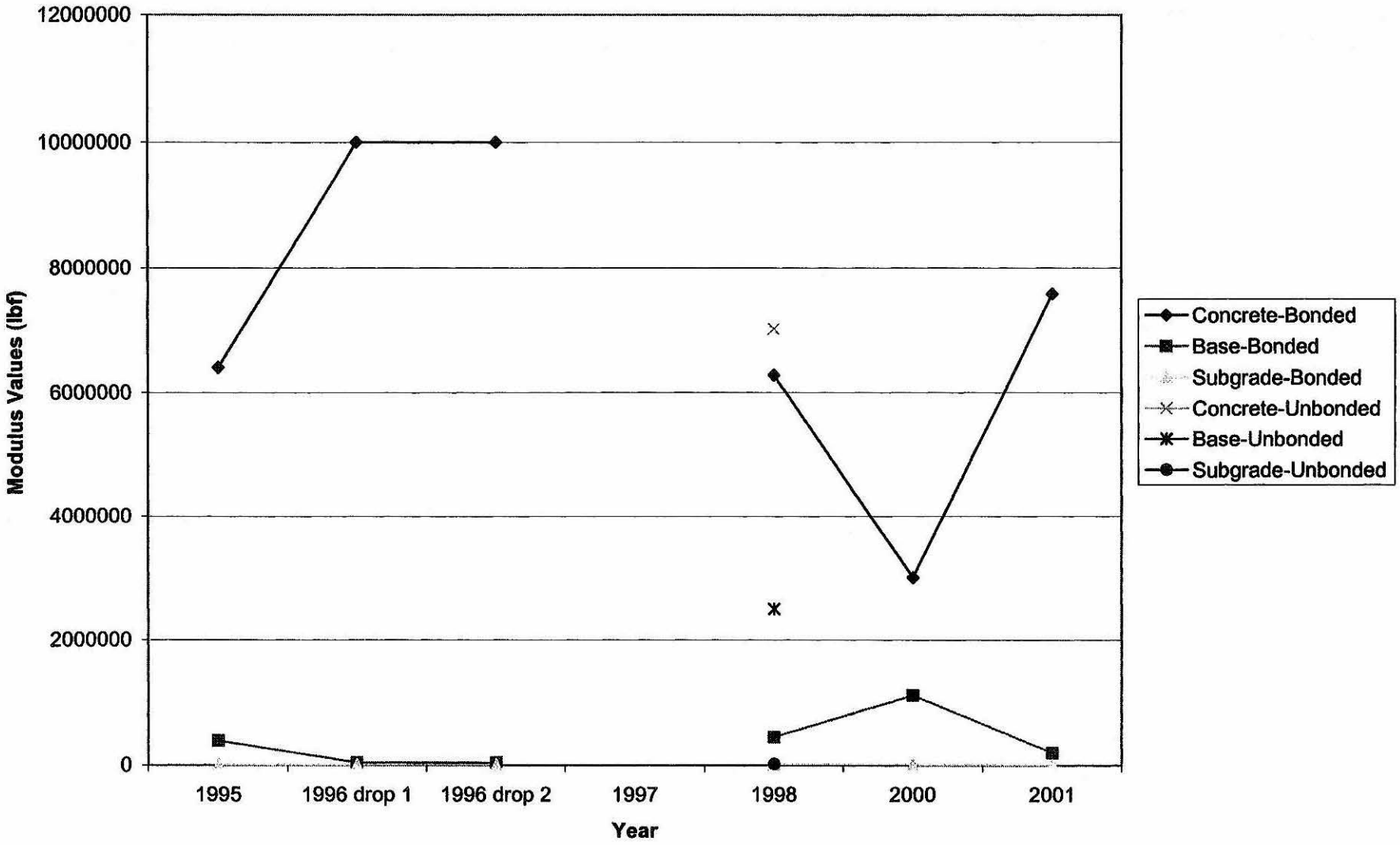
Station 2485+00, Northbound Lane



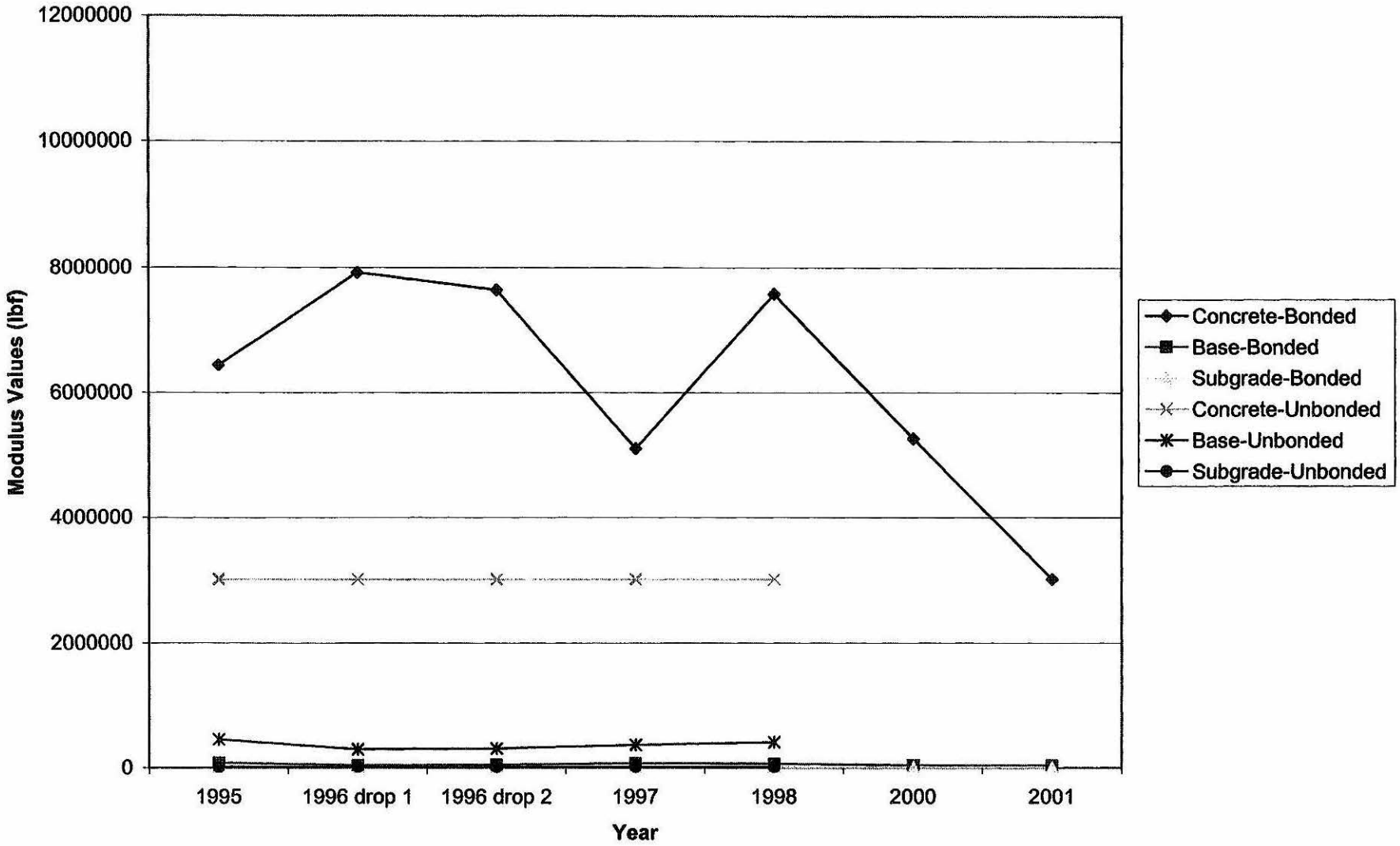
Station 2494+50, Northbound Lane

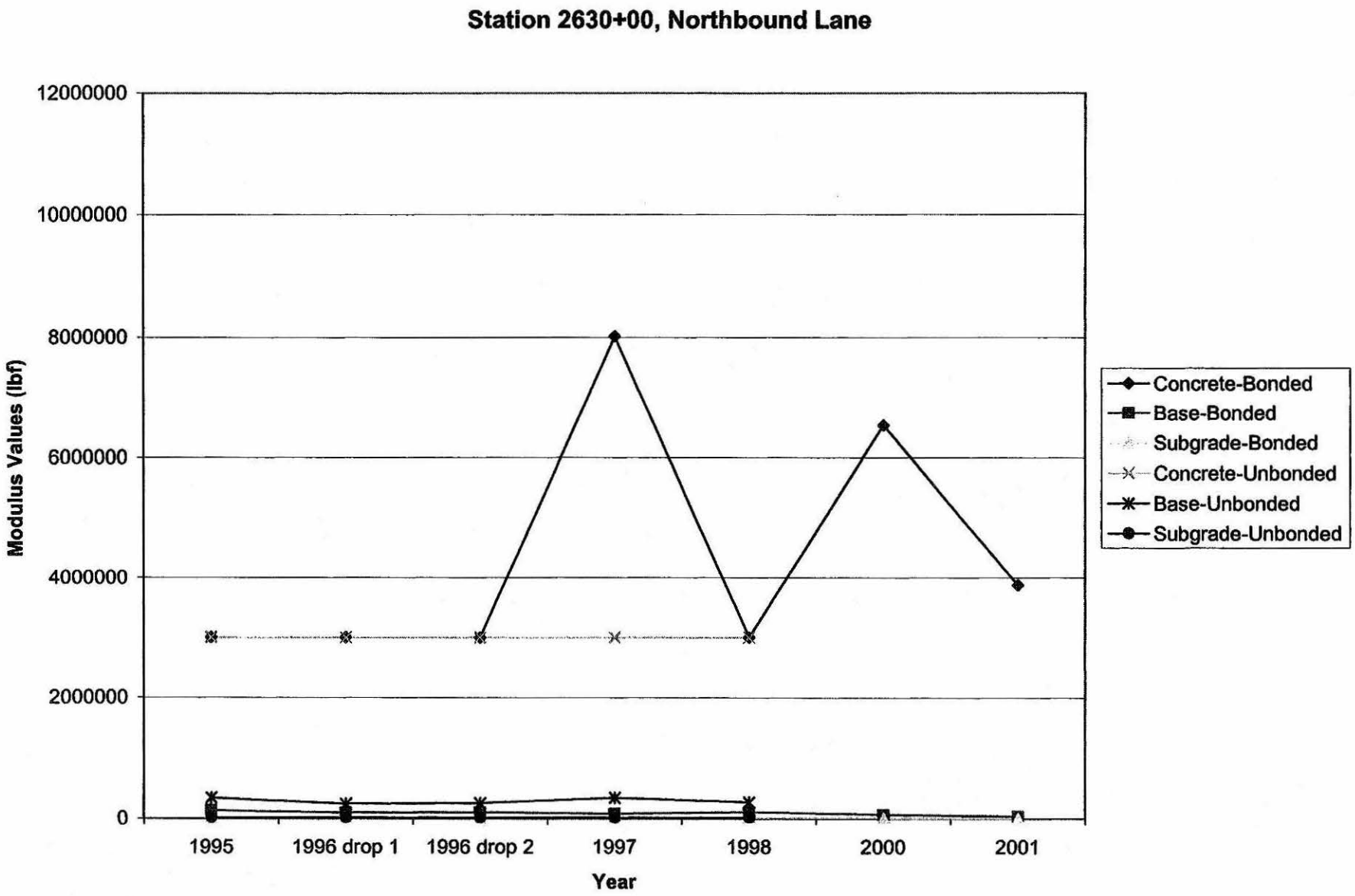


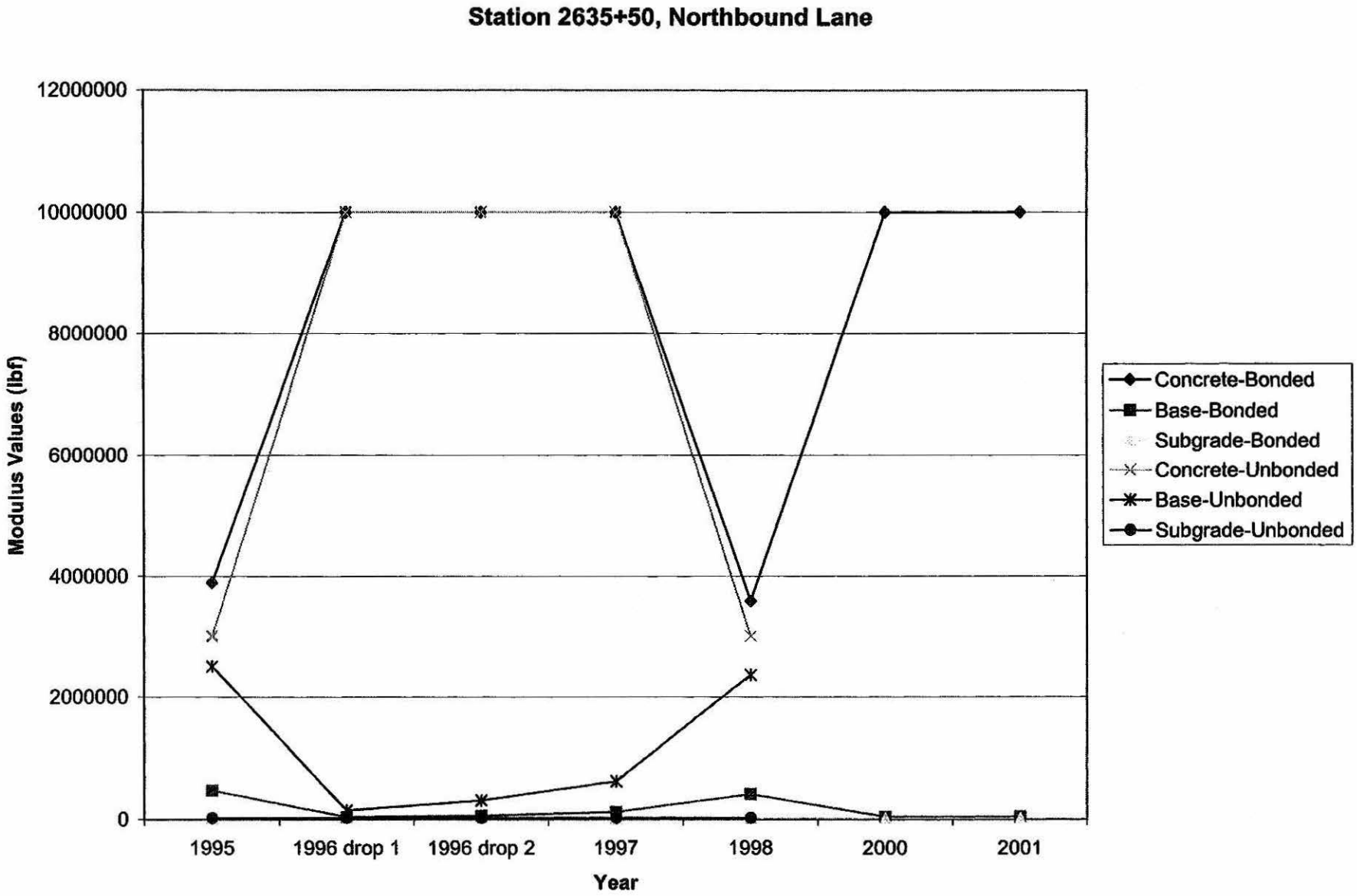
Station 2502+00, Northbound Lane



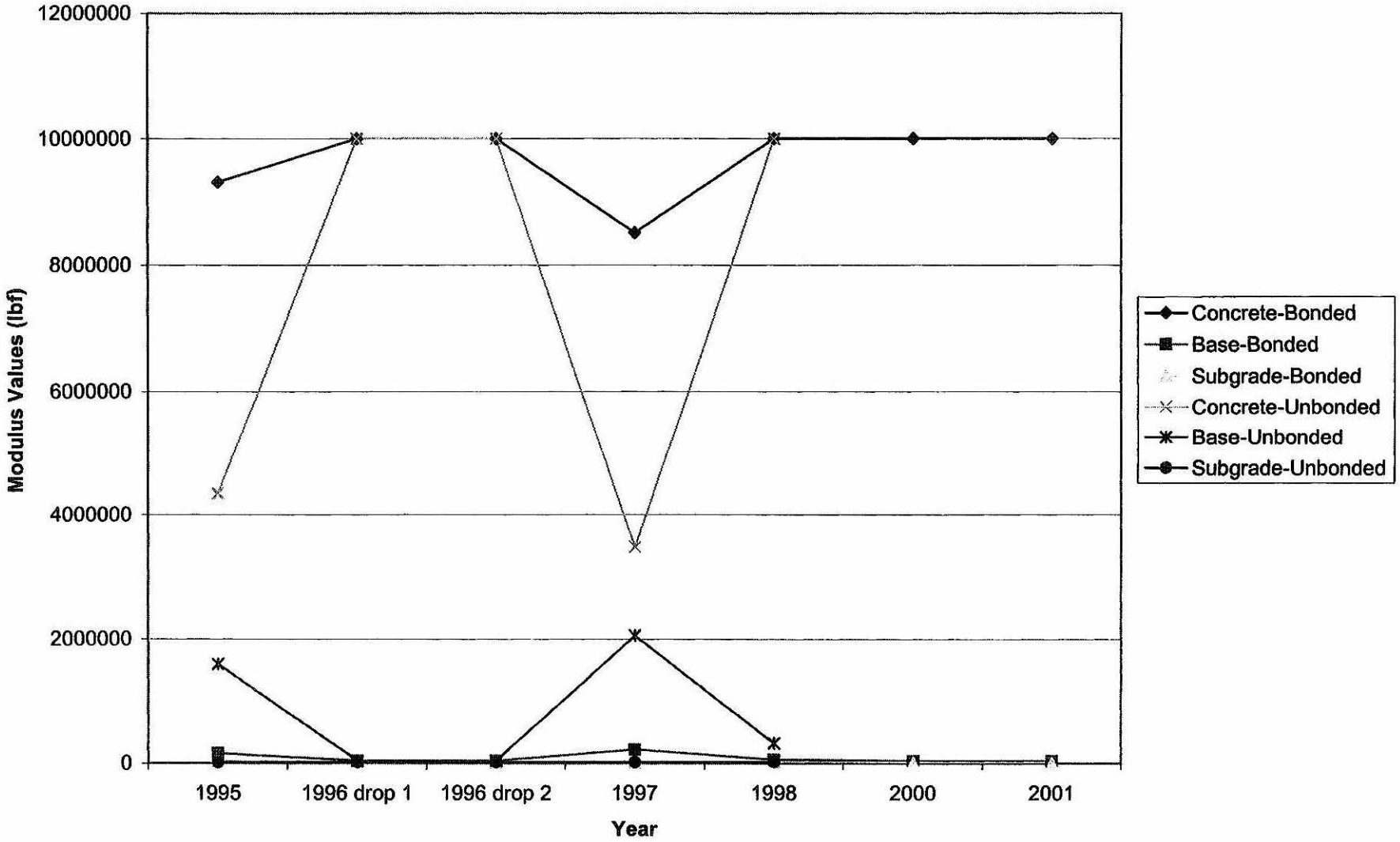
Station 2620+00, Northbound Lane



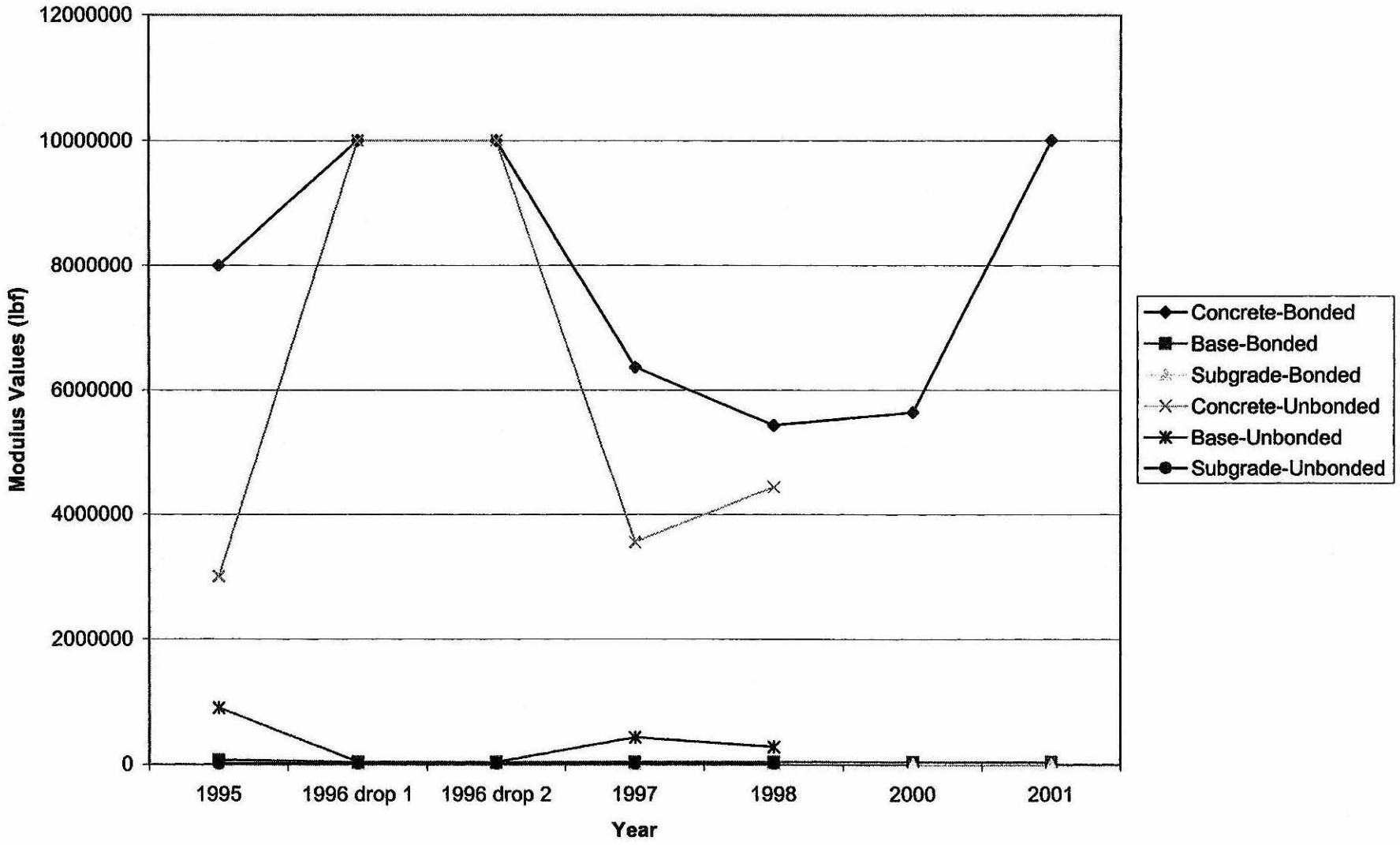

Station 2630+00, Northbound Lane
12000000
10000000
8000000
6000000
4000000
2000000
0
Modulus Values (lbf)
1995
1996 drop 1
1996 drop 2
1997
1998
2000
2001
Year
Concrete-Bonded
Base-Bonded
Subgrade-Bonded
Concrete-Unbonded
Base-Unbonded
Subgrade-Unbonded

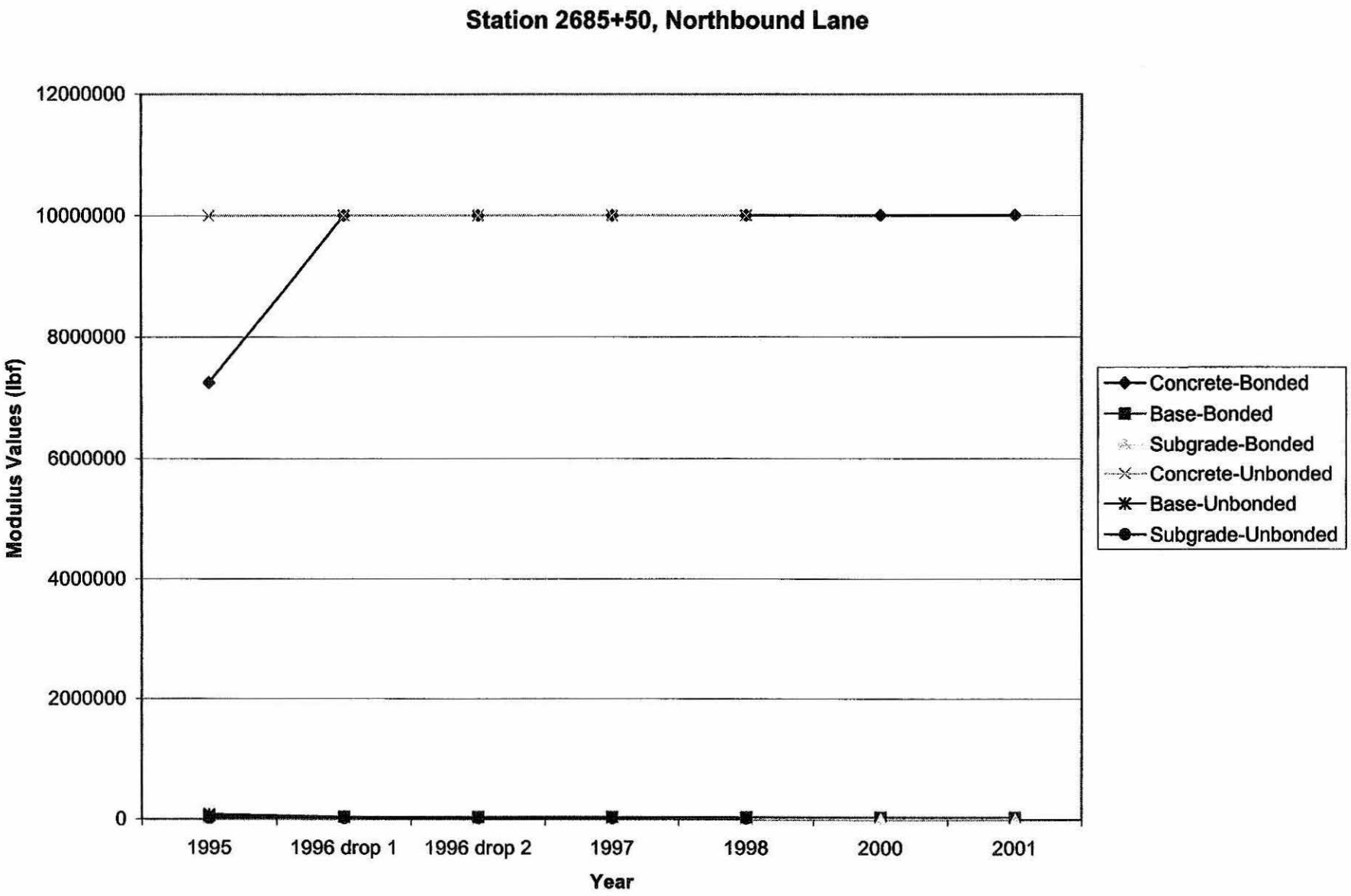

Station 2635+50, Northbound Lane
12000000
10000000
8000000
6000000
4000000
2000000
0
Modulus Values (lbf)
1995
1996 drop 1
1996 drop 2
1997
1998
2000
2001
Year
Concrete-Bonded
Base-Bonded
Subgrade-Bonded
Concrete-Unbonded
Base-Unbonded
Subgrade-Unbonded

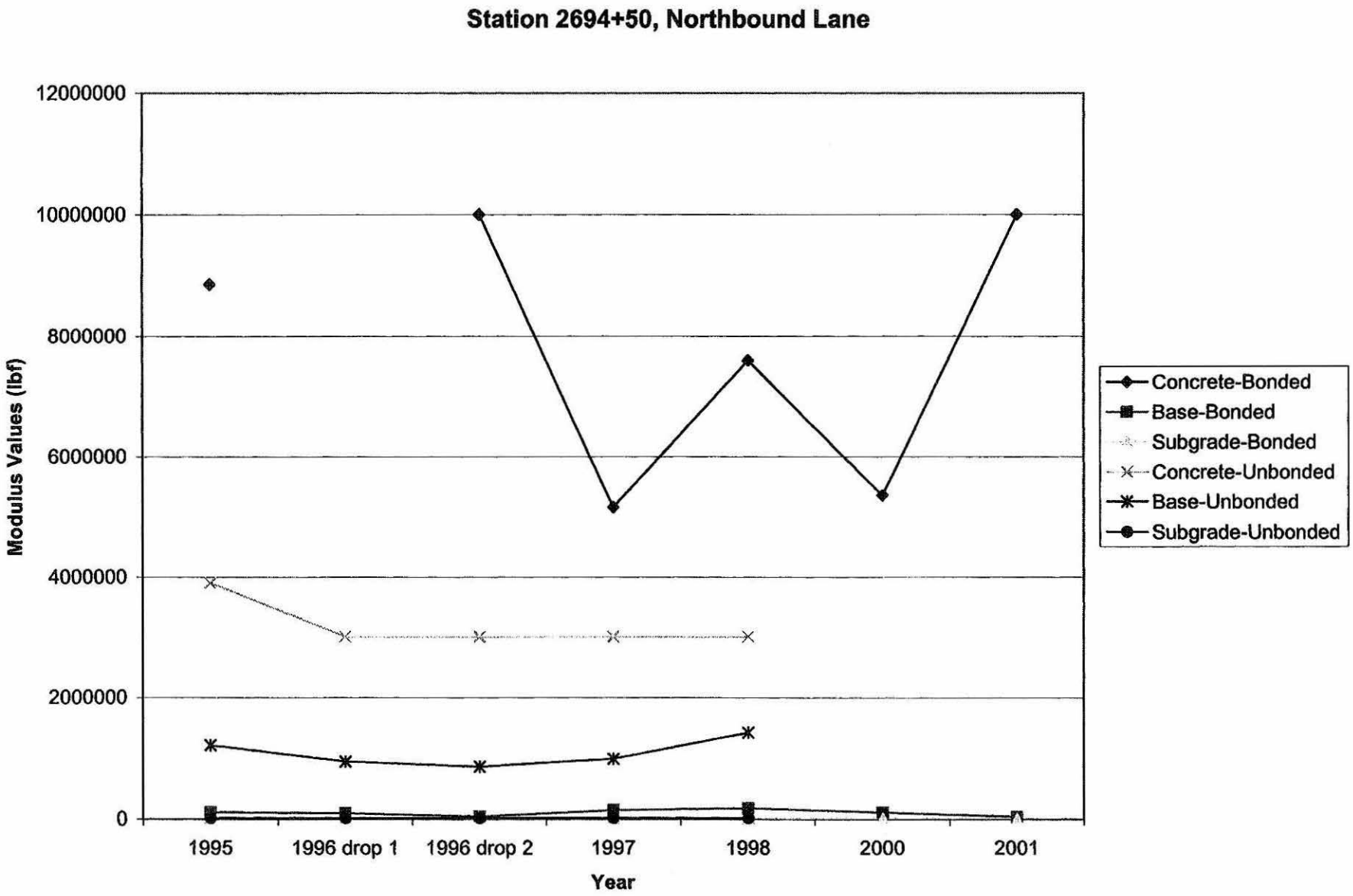
Station 2650+00, Northbound Lane

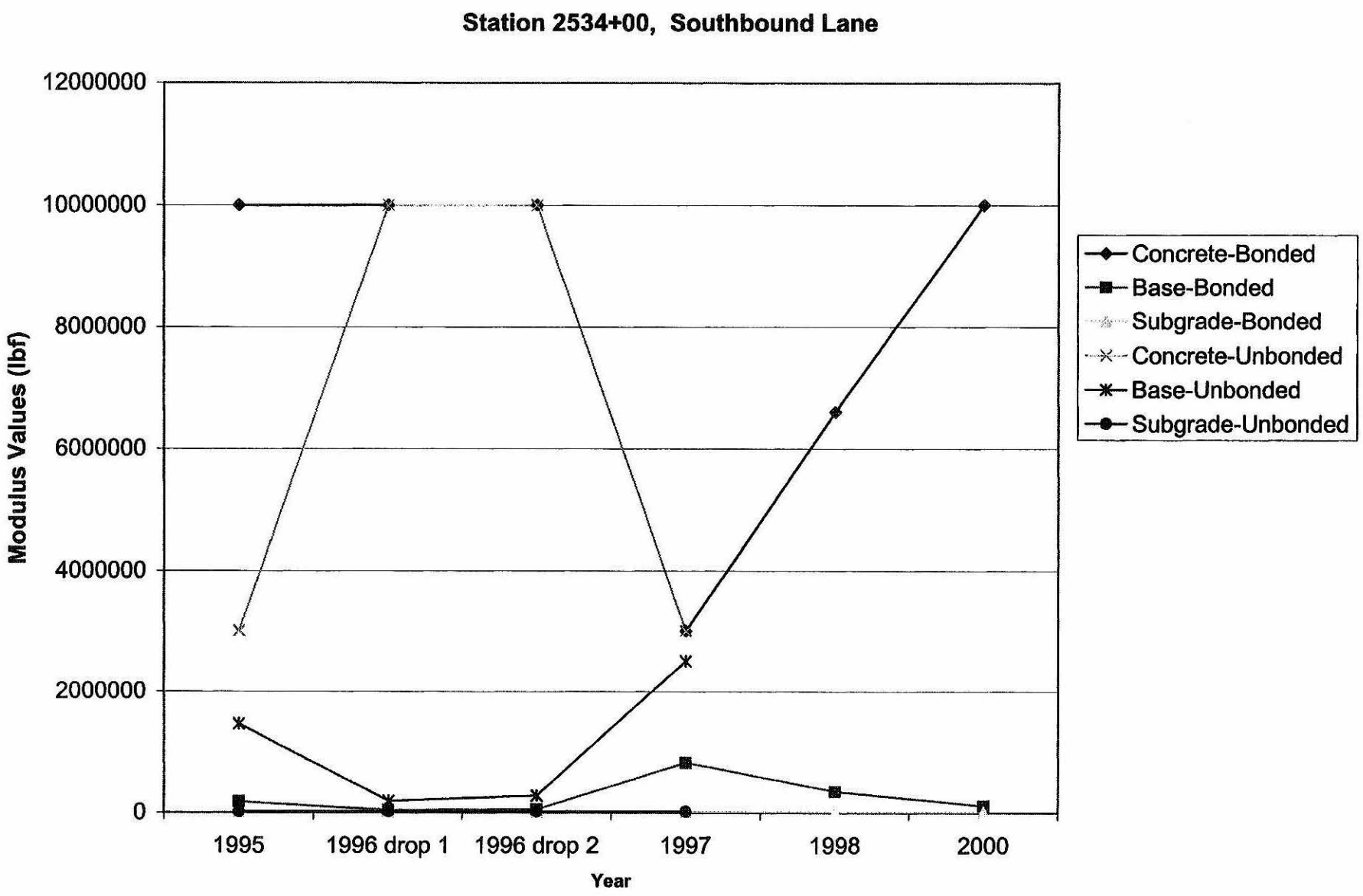


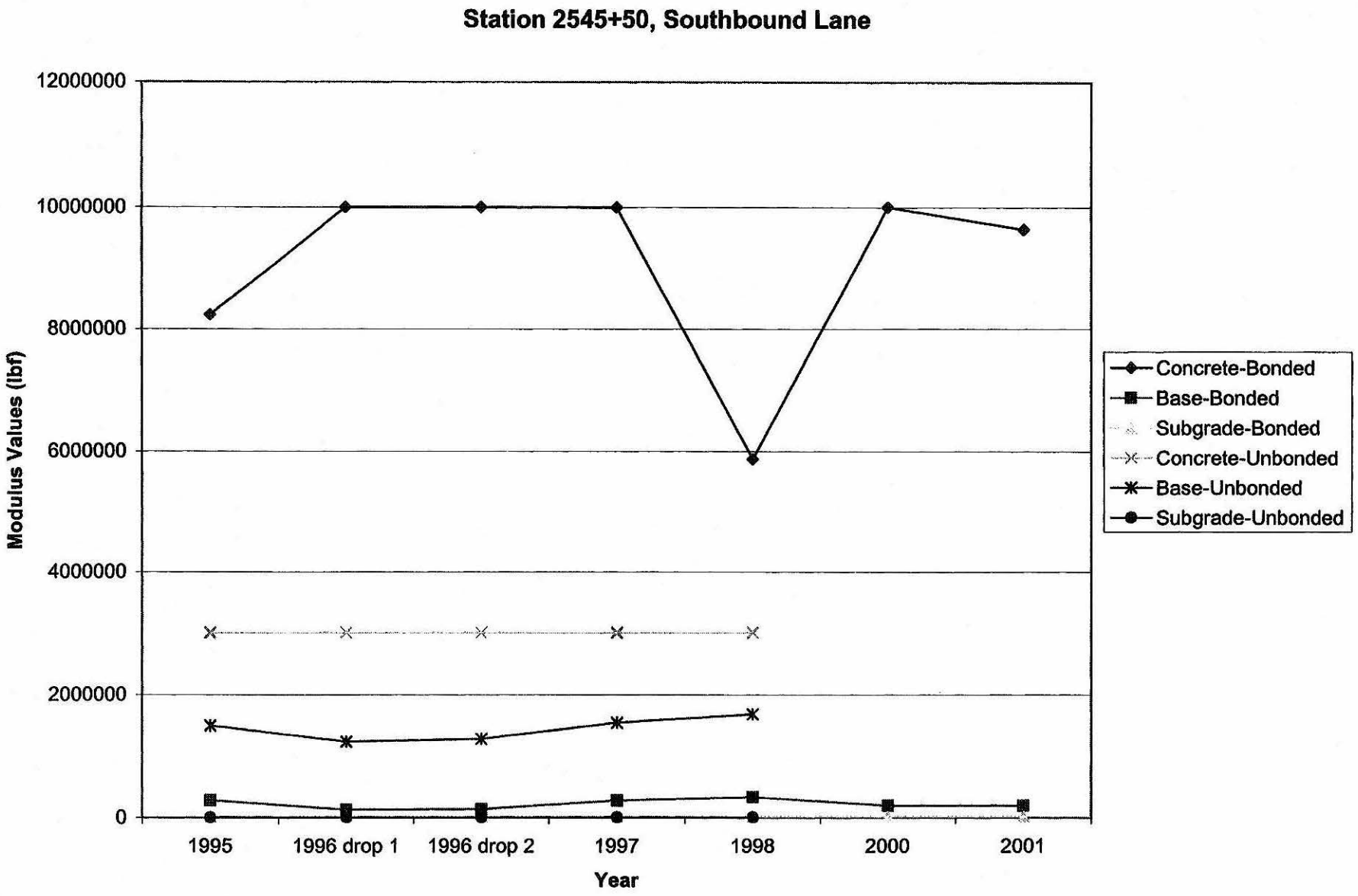
Station 2659+50, Northbound Lane

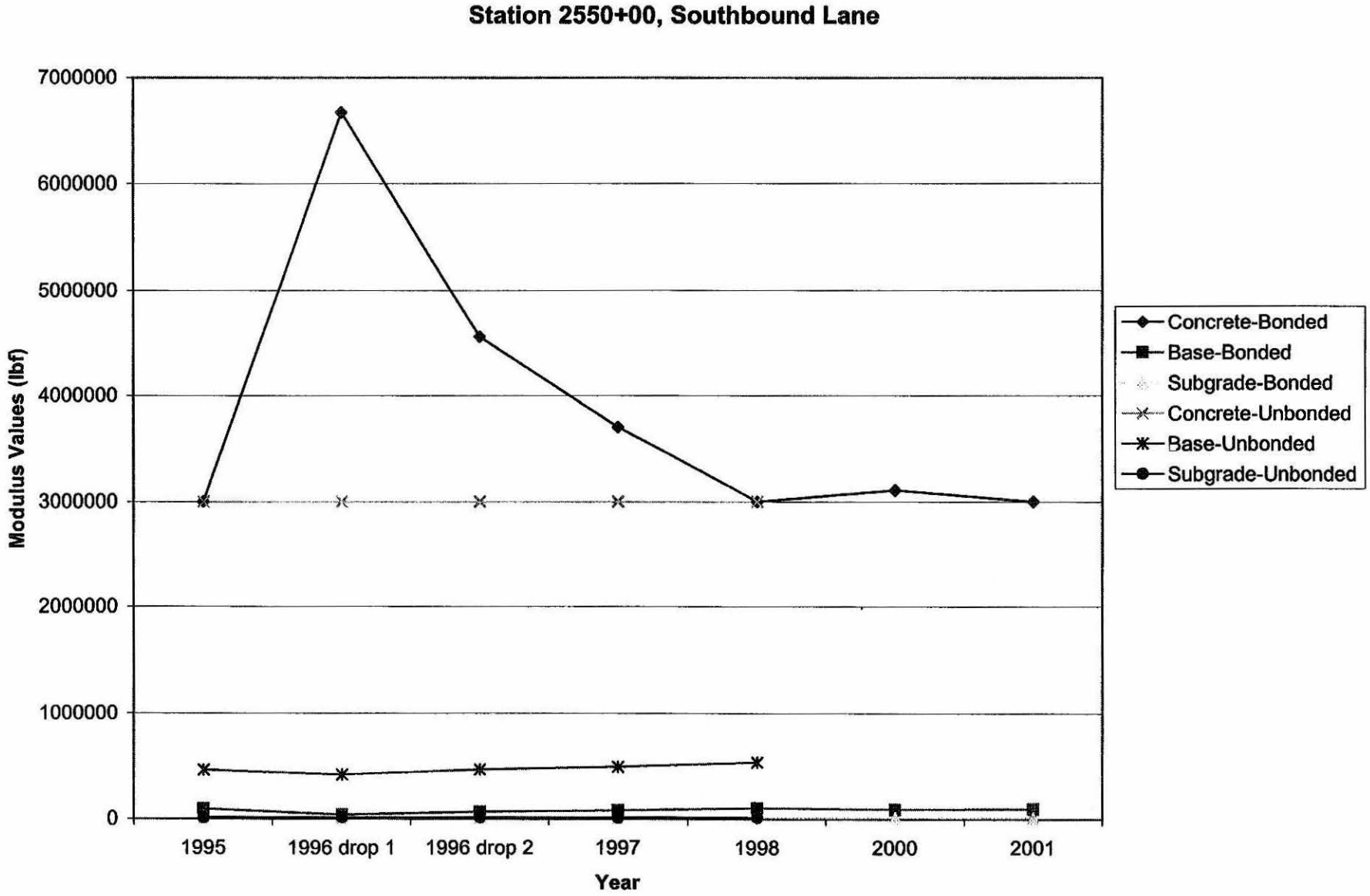



Station 2685+50, Northbound Lane
12000000
10000000
8000000
6000000
4000000
2000000
0
Modulus Values (lbf)
1995
1996 drop 1
1996 drop 2
1997
1998
2000
2001
Year
Concrete-Bonded
Base-Bonded
Subgrade-Bonded
Concrete-Unbonded
Base-Unbonded
Subgrade-Unbonded

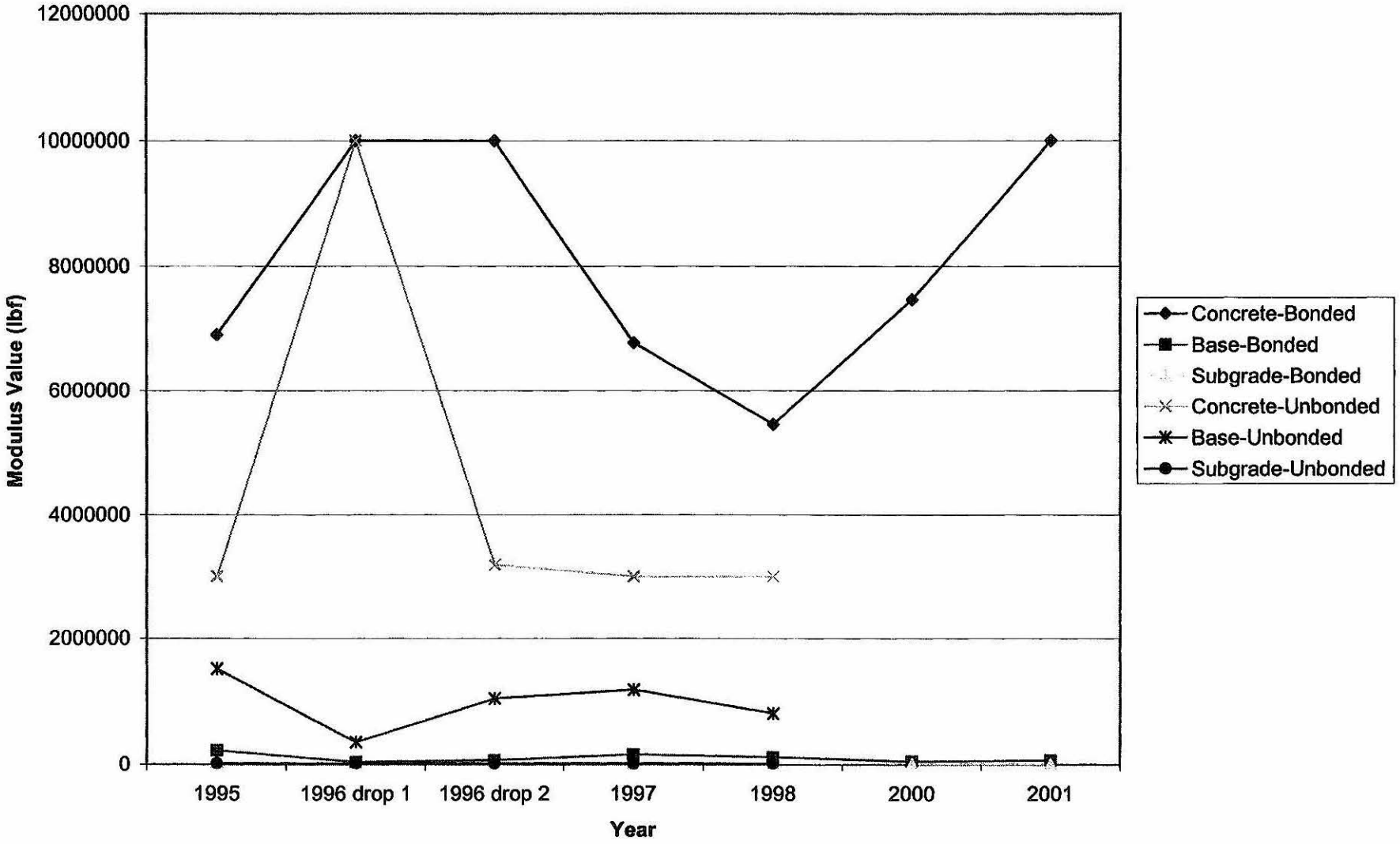

Station 2694+50, Northbound Lane
12000000
10000000
8000000
6000000
4000000
2000000
0
Modulus Values (lbf)
1995
1996 drop 1
1996 drop 2
1997
1998
2000
2001
Year
Concrete-Bonded
Base-Bonded
Subgrade-Bonded
Concrete-Unbonded
Base-Unbonded
Subgrade-Unbonded


Station 2534+00, Southbound Lane
12000000
10000000
8000000
6000000
4000000
2000000
0
Modulus Values (lbf)
1995
1996 drop 1
1996 drop 2
1997
1998
2000
Year
Concrete-Bonded
Base-Bonded
Subgrade-Bonded
Concrete-Unbonded
Base-Unbonded
Subgrade-Unbonded

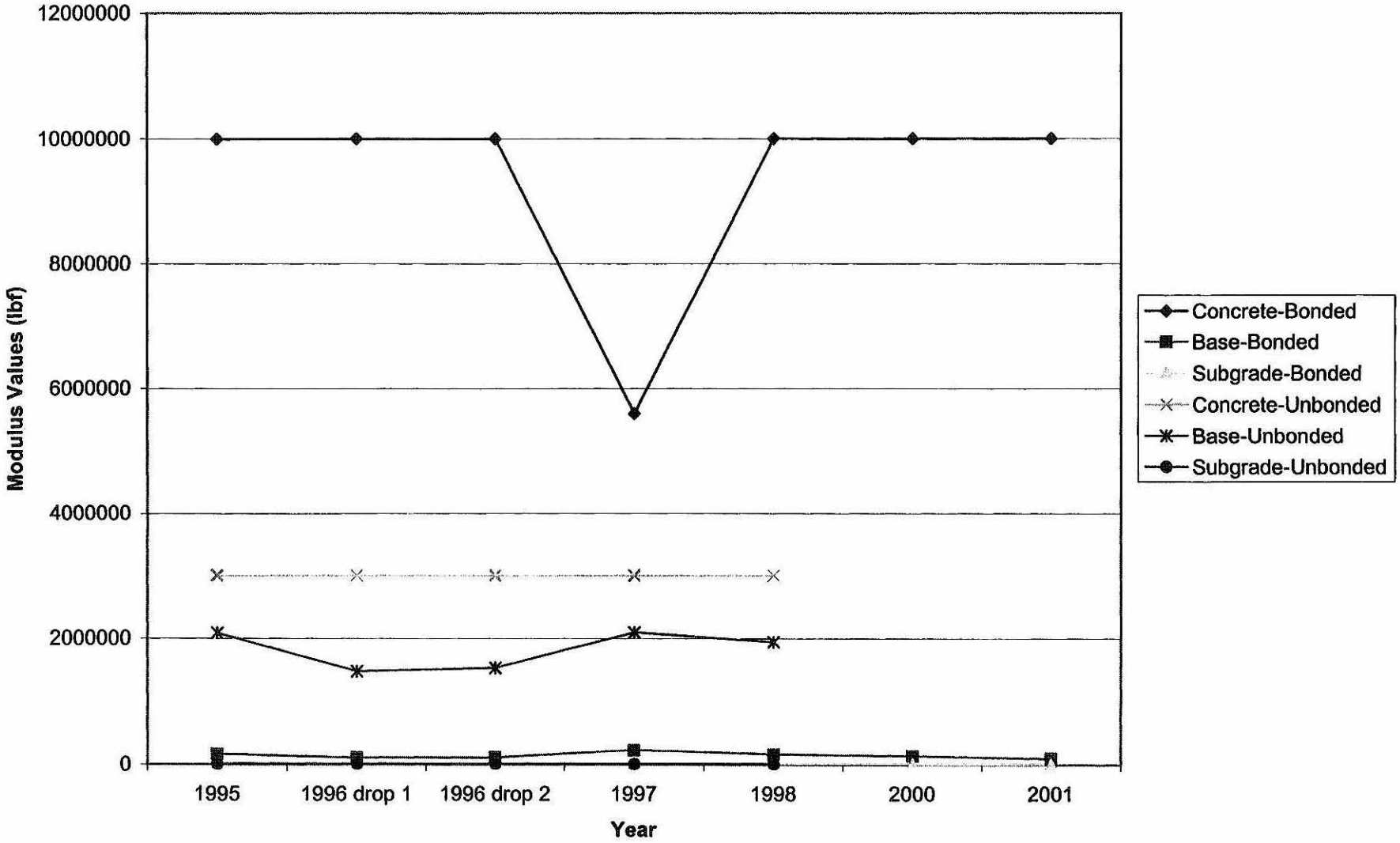

Station 2545+50, Southbound Lane
12000000
10000000
8000000
6000000
4000000
2000000
0
Modulus Values (lbf)
1995
1996 drop 1
1996 drop 2
1997
1998
2000
2001
Year
Concrete-Bonded
Base-Bonded
Subgrade-Bonded
Concrete-Unbonded
Base-Unbonded
Subgrade-Unbonded

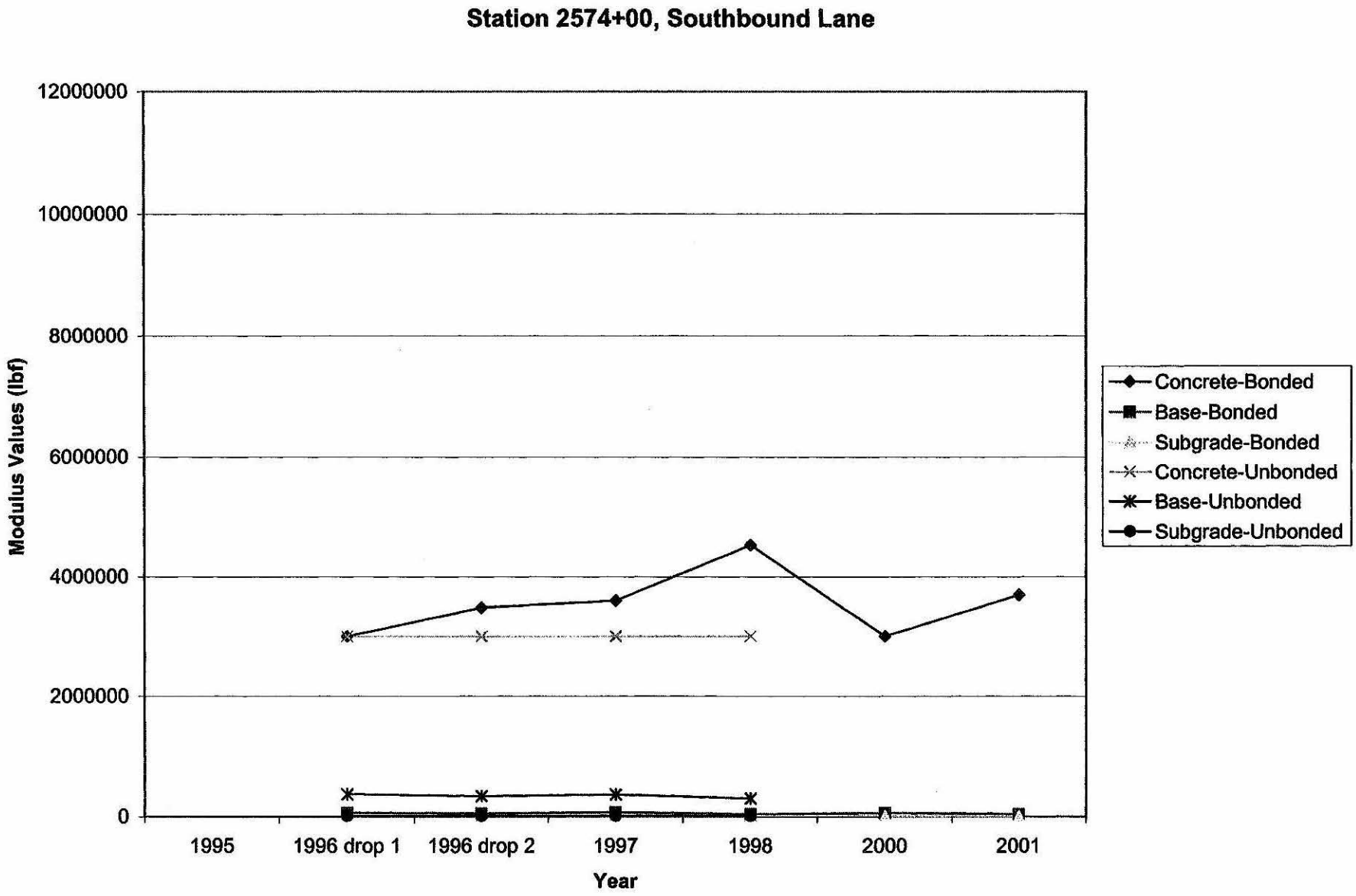

Station 2550+00, Southbound Lane
7000000
6000000
5000000
4000000
3000000
2000000
1000000
0
Modulus Values (lbf)
1995
1996 drop 1
1996 drop 2
1997
1998
2000
2001
Year
Concrete-Bonded
Base-Bonded
Subgrade-Bonded
Concrete-Unbonded
Base-Unbonded
Subgrade-Unbonded

Station 2560+00, Southbound Lane

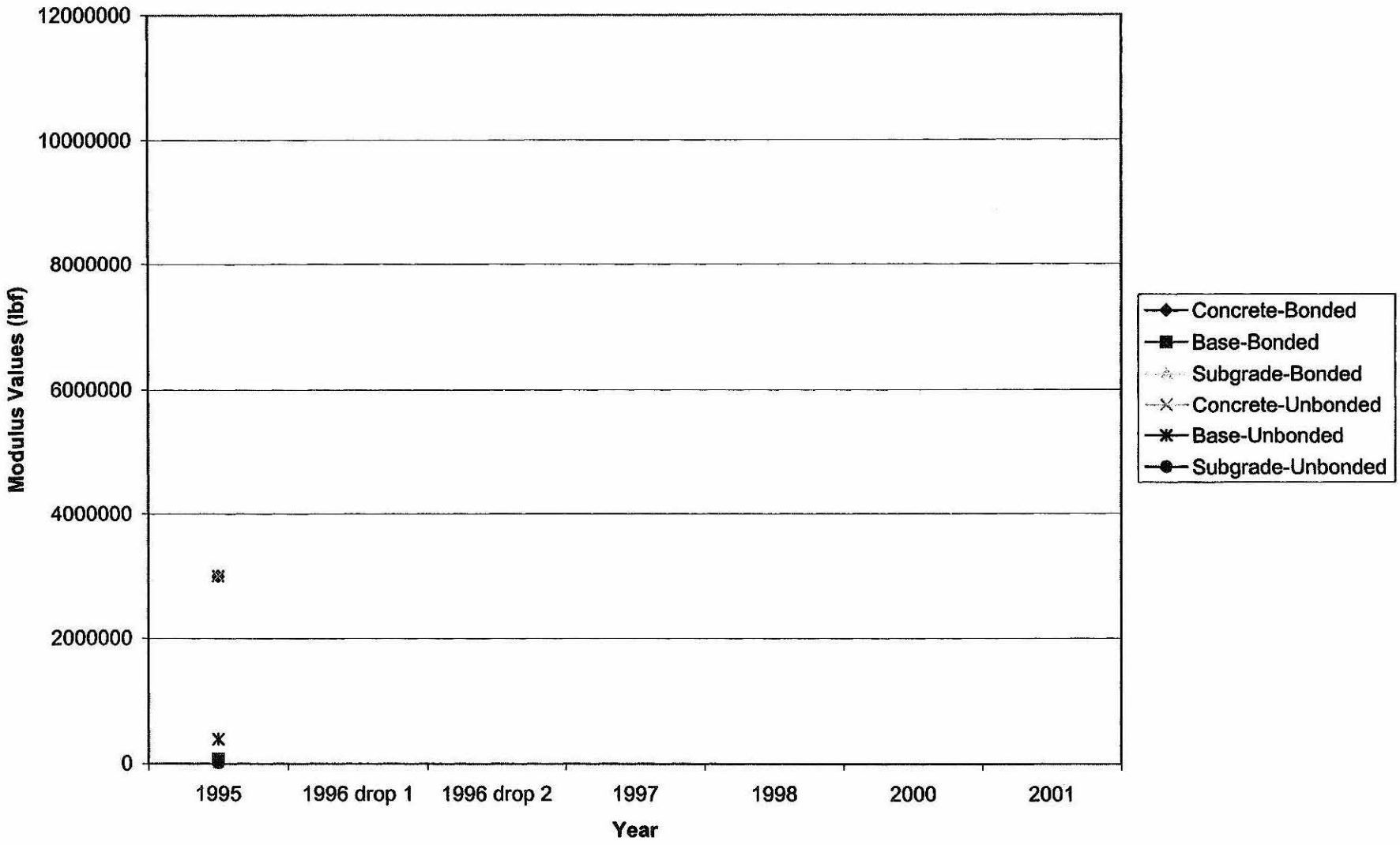


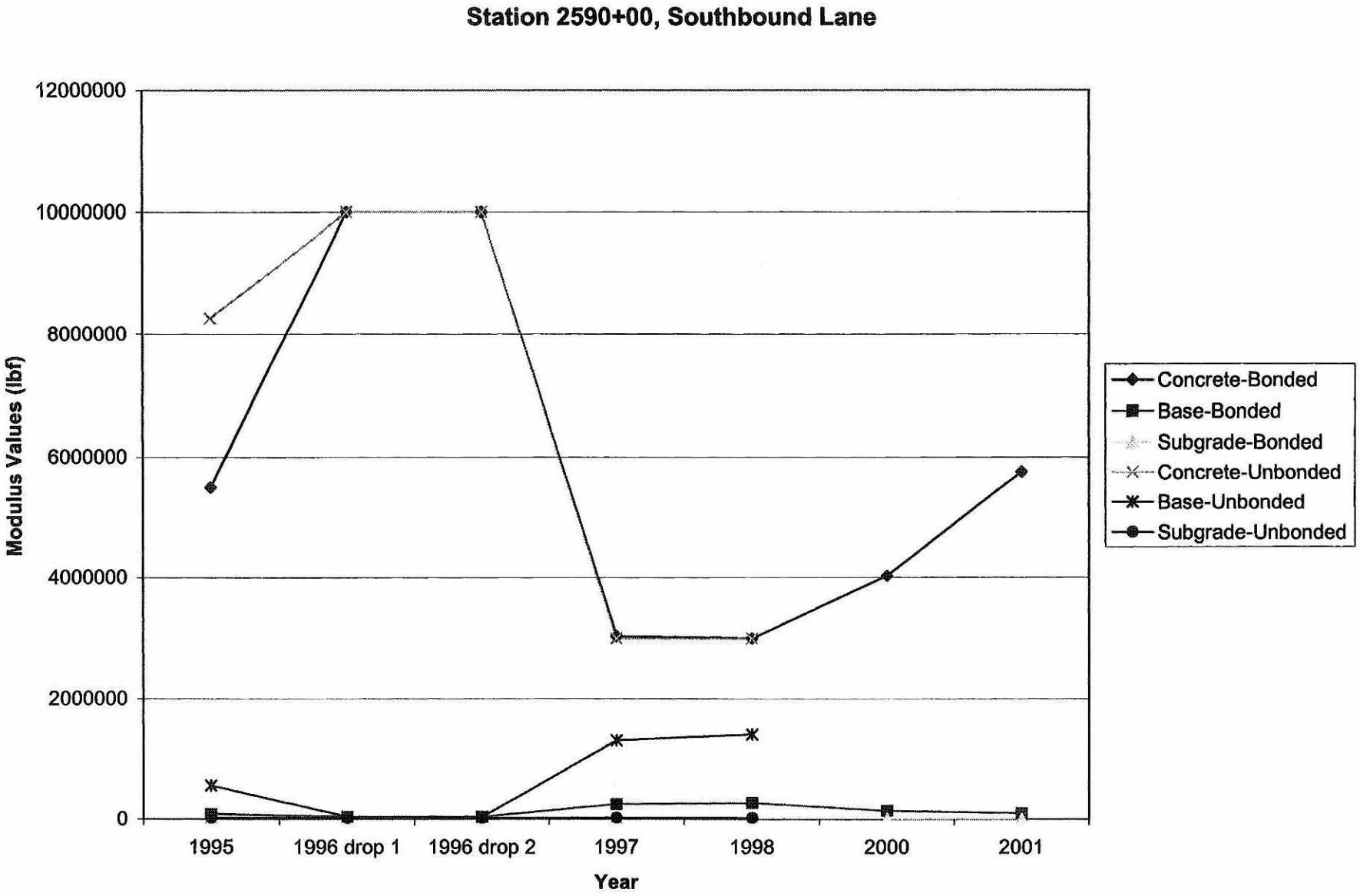
Station 2565+00, Southbound Lane



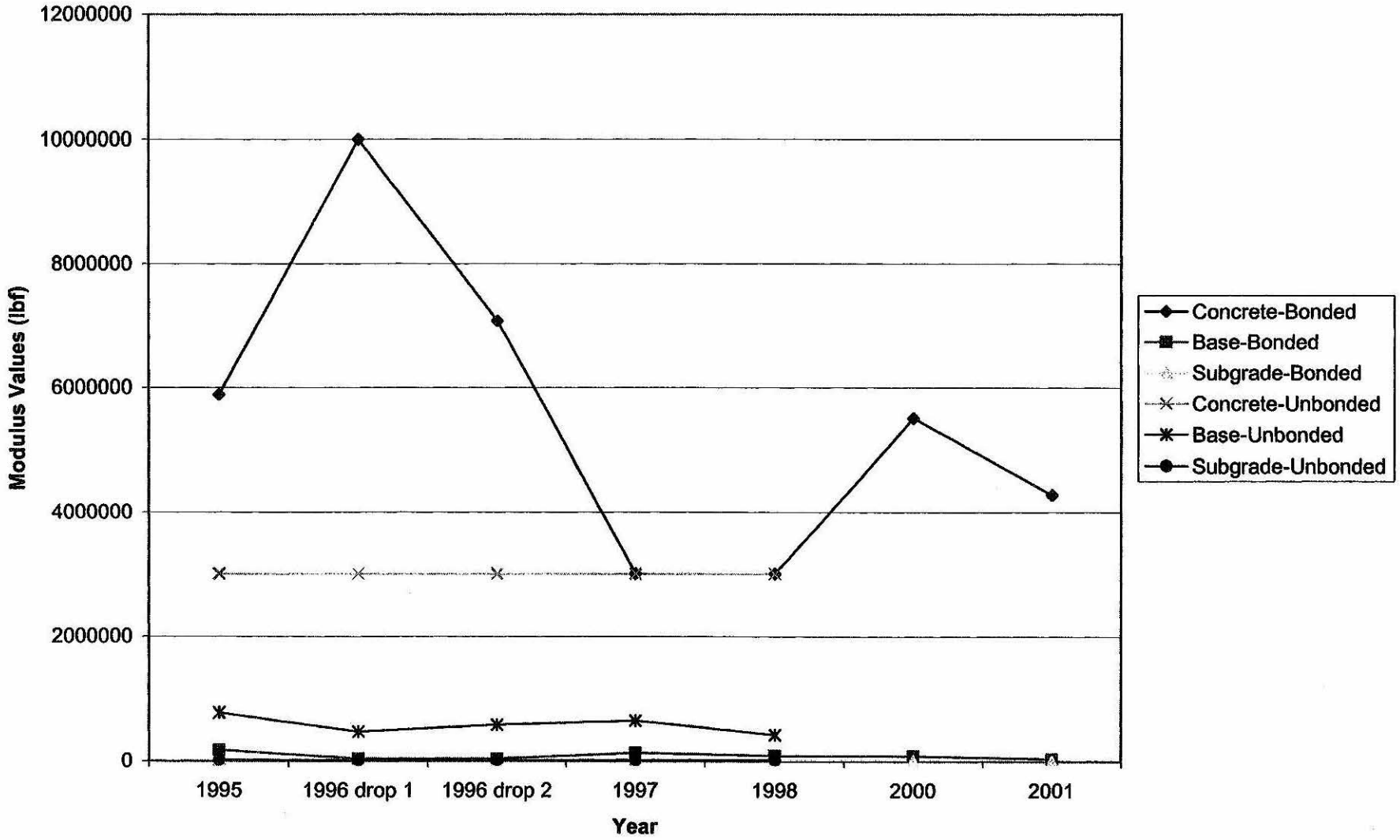

Station 2574+00, Southbound Lane
12000000
10000000
8000000
6000000
4000000
2000000
0
Modulus Values (lbf)
1995
1996 drop 1
1996 drop 2
1997
1998
2000
2001
Year
Concrete-Bonded
Base-Bonded
Subgrade-Bonded
Concrete-Unbonded
Base-Unbonded
Subgrade-Unbonded

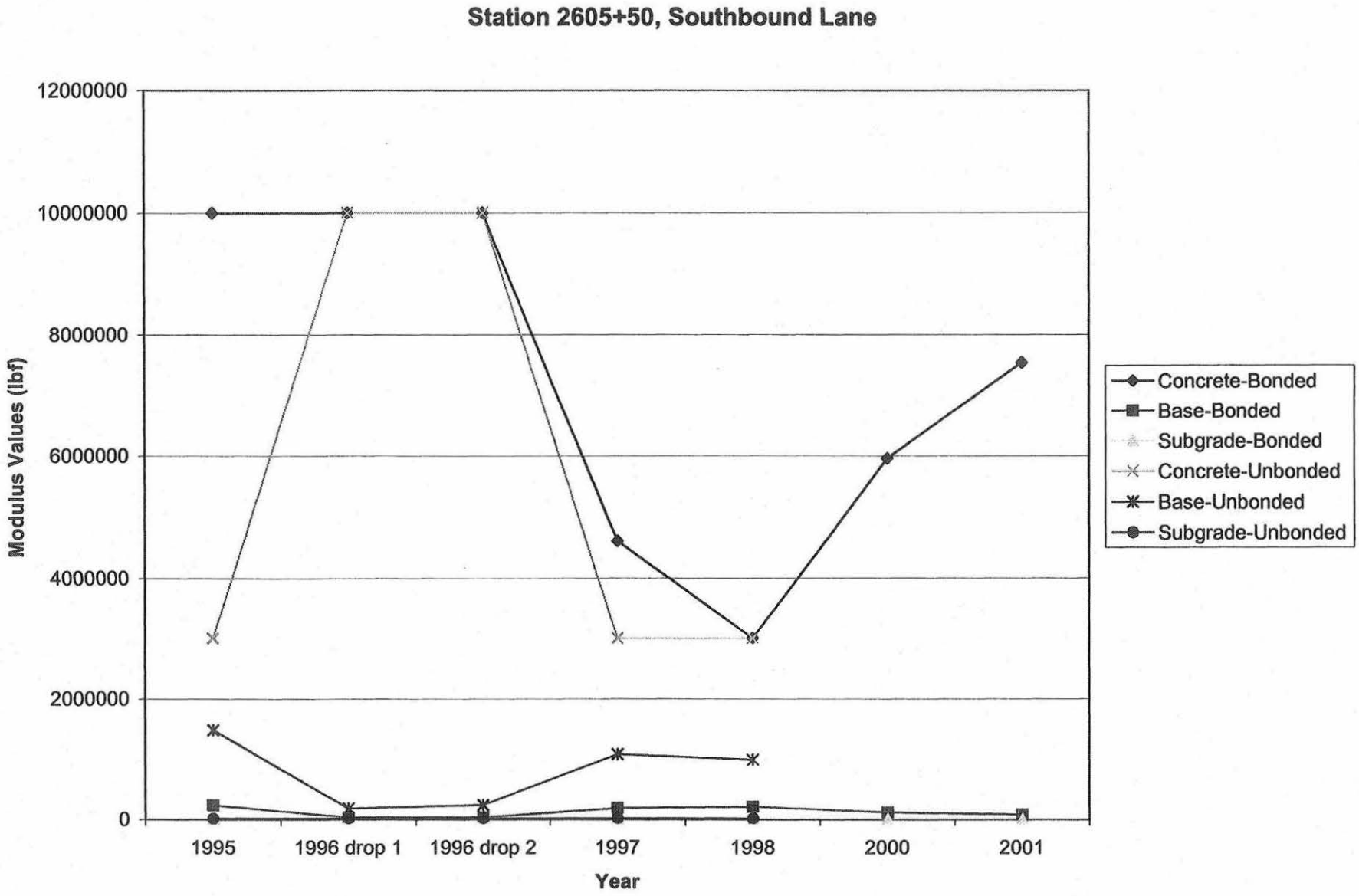
Station 2575+00, Southbound Lane

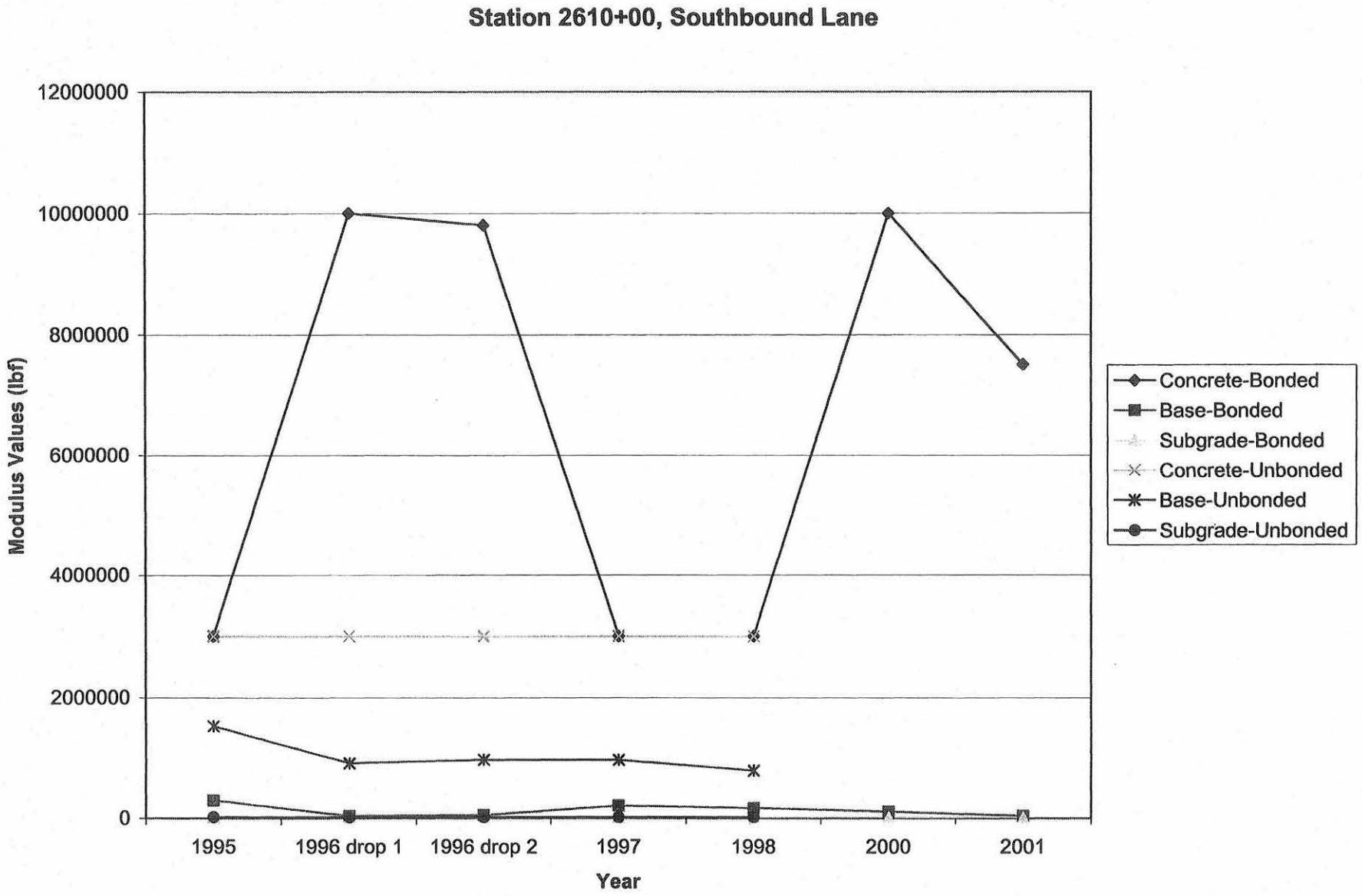


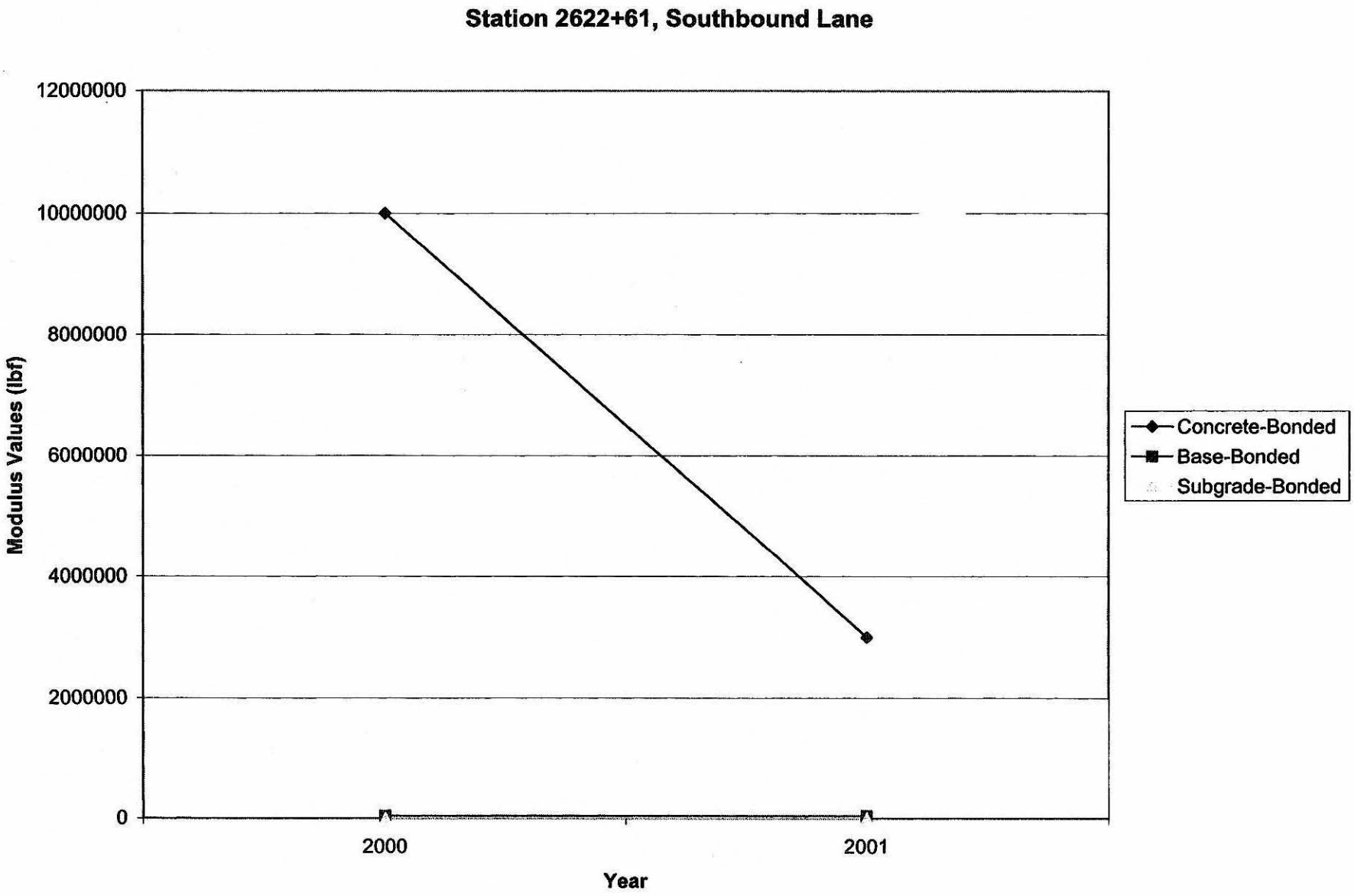

Station 2590+00, Southbound Lane
12000000
10000000
8000000
6000000
4000000
2000000
0
Modulus Values (lbf)
1995
1996 drop 1
1996 drop 2
1997
1998
2000
2001
Year
Concrete-Bonded
Base-Bonded
Subgrade-Bonded
Concrete-Unbonded
Base-Unbonded
Subgrade-Unbonded

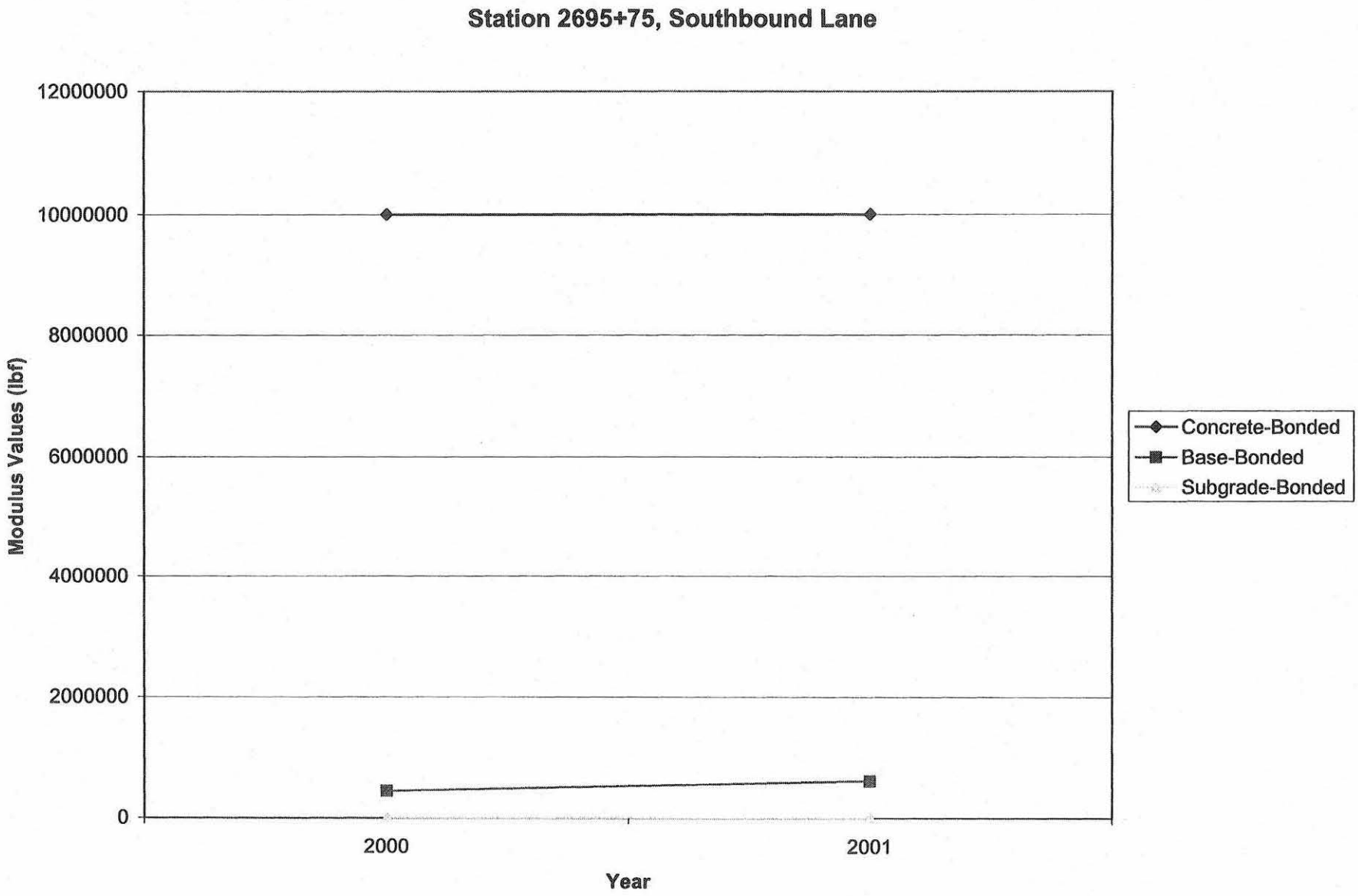
Station 2596+00, Southbound Lane

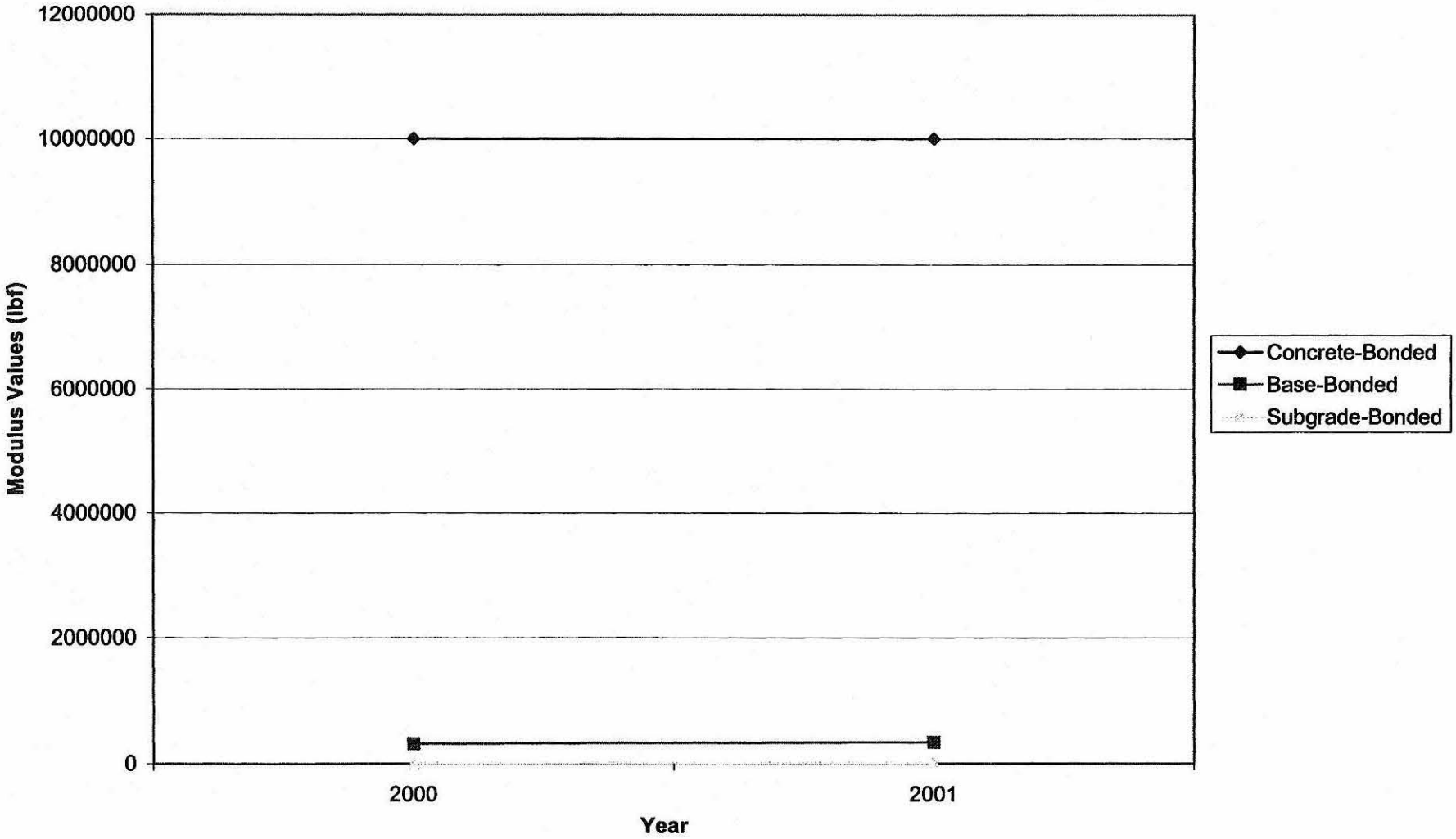



Station 2605+50, Southbound Lane
12000000
10000000
8000000
6000000
4000000
2000000
0
Modulus Values (lbf)
1995
1996 drop 1
1996 drop 2
1997
1998
2000
2001
Year
Concrete-Bonded
Base-Bonded
Subgrade-Bonded
Concrete-Unbonded
Base-Unbonded
Subgrade-Unbonded


Station 2610+00, Southbound Lane
12000000
10000000
8000000
6000000
4000000
2000000
0
Modulus Values (lbf)
1995
1996 drop 1
1996 drop 2
1997
1998
2000
2001
Year
Concrete-Bonded
Base-Bonded
Subgrade-Bonded
Concrete-Unbonded
Base-Unbonded
Subgrade-Unbonded


Station 2622+61, Southbound Lane
12000000
10000000
8000000
6000000
4000000
2000000
0
Modulus Values (lbf)
2000
2001
Year
Concrete-Bonded
Base-Bonded
Subgrade-Bonded


Station 2695+75, Southbound Lane
12000000
10000000
8000000
6000000
4000000
2000000
0
Modulus Values (lbf)
2000
2001
Year
Concrete-Bonded
Base-Bonded
Subgrade-Bonded


Station 2697+25, Southbound Lane
12000000
10000000
8000000
6000000
4000000
2000000
0
Modulus Values (lbf)
2000
2001
Year
Concrete-Bonded
Base-Bonded
Subgrade-Bonded